DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Growth of Chemical Output is Checked

So far, virtue in the chemical industries—a high rate of investment in research and production—has been well rewarded. Since 1948 general industrial output has risen by about two-fifths; production of the chemical industry has doubled. Now the general stagnation of the economy is inevitably having its effect even on this thriving industrial group. A recent Treasury Bulletin for Industry reports a marked slowing down of its growth in the fourth quarter of 1957. After a 6% rise in output in the first half of 1957, chemicals production in the second half was only 2% above a year earlier. Towards the end of the year the rate of increase over a year earlier slowed down in the paint and plastics sectors; by the end of the year output of general chemicals was running below a year earlier. The rate of increase in the consumption of sulphuric acid, a pointer to activity both in the chemicals group and in industry as a whole, fell from 6% above a year earlier in the first three-quarters of 1957 to 4½% above in the fourth, and in the first quarter of 1958 consumption was a little lower than a year earlier.

Much of the rise in production in the first part of 1957 was due to increased exports. This increase had ended by the fourth quarter, when the volume of exports was marginally lower than a year earlier, compared with a rise of 12% in the first three-quarters. The industry has begun to face some setback overseas as a consequence of the general recession of demand and increasing competition among producers. Can one industry fight against a widespread economic trend, or is this the stage to press for government action to remove restrictions and encourage the resumption of general industrial growth in Britain?

Cui Bono

"What is the purpose of our activities?" asked Professor W. Wardlaw in his recent Presidential Address to the Royal Institute of Chemistry. In contrast with the present range and vitality of the chemical industries Dr. Wardlaw recalled their scope before the first world war. The main concern was the manufacture of heavy chemicals, although dyestuffs and intermediates were made on a limited scale. In this country we relied on Germany to provide us with the bulk of dyestuffs, fine chemicals, drugs, pharmaceuticals, laboratory glassware and scientific instruments. Consequently the outbreak of war with Germany in 1914 placed the country in a difficult position. Then began the process of educating our masters. As they became convinced of the value of science in war and peace, so gradually the status of science improved. Salary levels have risen, facilities for training expanded. In the inner development of chemistry the resurgence of inorganic chemistry has been a notable feature. This is a consequence of the demands of nuclear power, rocket and jet propulsion and electronics. Every year now sees new applications of chemical science in the service of mankind and the opening up of new fields of activity for the professional chemist. And the President's final answer to his opening rhetorical query was quoted from the words of Montaigne "I am of opinion that the most honourable calling is to serve the Public and to be useful to the many."

Do we need a Standard Gas for Calorimetry Checks?

CYLINDERS of standard gas having a certified heating value of approximately 1000 Btu/ft.³ may now be obtained in the U.S.A. from the National Bureau of Standards. This service is the result of a co-operative research effort by the Bureau and the Research Committee of the American Gas Association to develop a reference gas, certification procedure and calorimetric test methods acceptable to the utilities marketing natural gas as a fuel. The gas is used to calibrate recording calorimeters. We understand that there is some interest at the National Physical Laboratory in this development but first reactions of engineers concerned with gas quality in Britain are that there is no need for a comparable service here. Recording calorimeters are verified against standard calorimeters which are themselves ultimately checked against pure hydrogen. Responsibility for checking accuracy—formerly the business of the Gas Referees—now lies with the Gas Standards Branch of the Ministry of Power. Opinion in Britain inclines to the view that there would be no function here for a specially prepared standard gas.

New Look for Jute

FUTURE penitents may find sackcloth inadequate for their purpose if certain lines of jute research prove successful. At Dundee—close to the main producing section of the jute industry—a vigorous, rapidly expanded research association is paying special attention to improving the finish of their tough but coarse product. In this field can be listed rot-proofing, treatment to minimize degradation effect of acid atmospheres, the "marriage" of jute with other substances such as plastic films and paper, and fireproofing. One line of chemical treatment of the flax results in a new type of packaging material—an anti-corrosive jute wrapping and fibrous material for use with bright steel and cast iron. Mr. H. Corteen, the Director, informs us that the research station now covers an area of over 30,000 sq. ft. of which approximately half is devoted to research laboratories and the remainder to large-scale processing facilities including a small chemical engineering section.

New instruments and proto-type machines have been developed. Two of the devices have already proved their worth in operation. One of the products is an automatic tensile tester which builds up a histogram of individual yarn sample strengths, by testing several hundred successive individual yarn samples per hour. Another impressive achievement is a continuous moisture tester which is applicable to any products where the specific gravity is reasonably constant over the range of mixtures to be tested.

Automation in the Oil Industry

TO the oil industry only the *word* "automation" is new. The concept and—in an appreciable degree—the practice is well-established. This gives a unique background of experience on which MR. S. W. J. WALLIS (of British Petroleum Co., Ltd.) was able to draw when he boldly set out to consider the probable evolution of the subject. Effort is now being directed toward closing the gaps that exist between stable and optimal operation, and there are two important aspects which are receiving close attention. The first of these involves development and manufacture of certain types of new equipment while the second is to provide the trained manpower able to apply and maintain it.

In the first case developments of primary interest are centred on the automatic analysis of product quality and measuring devices of greater accuracy including a mass flowmeter. Satisfactory operation of stream quality analysers would go a long way toward achieving optimal control but it will be necessary to develop the decision making equipment to act on the data obtained. This will obviously be some form of computer. Emphasis has shifted rapidly from instrumentation to the wider topic of control engineering, involving the integration of all groups engaged in the design and operation of process plant. This takes engineers into new fields of engineering and requires a broader education; it means re-casting of apprenticeship schemes and all other levels of education including adult training.

Will these developments cut staffs? MR. WALLIS argued the contrary case. One notable result of making maximum use of new developments as and when they were available has been to reduce the manpower requirement for existing and new plant. Consequently the oil industry works with a comparatively small operating staff of high calibre. It is extremely doubtful whether any significant economy in overall manpower requirement can be made by further advance in the field of automation. More likely is an increase in overall manpower the nearer we approach to full automation. This increase would, of course, be offset by more profitable operation of the process plants. The address formed part of a Conference accompanying the recent Instruments, Electronics and Automation Exhibition.

Monitor for Water Vapour in Carbon Dioxide

SPECIAL requirements for leak detection in the heat exchangers of nuclear power stations led to the need for a critical appraisal of possible water vapour monitors. The resulting report* is likely to be of interest in many other fields of work. The core of reactors of the Calder Hall type is cooled by carbon dioxide which is circulated through four parallel systems of blowers and heat exchangers. An instrument was required to meet this specification:

(*a*) continuously indicate water vapour over the range 0°C to 20°C at dew-point, under reactor conditions of 115 lb./sq. in. absolute and 50°C;

(*b*) indicate on a scale of percentage by weight of water and, under steady conditions, to within + 5% of the steady value over any period of two minutes;

(*c*) indicate half the value of any step-function increase in water-vapour content within 20 seconds.

Neither the standard of accuracy nor the stability of the instrument thus specified was particularly high. The minimum step-function change in leak rate which could be reliably detected by an instrument which just satisfies the specification amounts to a 10% increase in moisture content, so that a 5% change could be indicated in 20 seconds. The 10% increase in moisture content corresponds to a change in leak rate of approximately 5.5 grammes of water per second or about 20 kg per hour. Other conditions were that the instrument should be insensitive to changes in gas pressure and temperature, and be unaffected by ambient changes. It also should be readily set up and serviced and be able to give a remote indication.

The choice resolved itself into a problem of considering adsorption elements or optical analysers of the infrared absorption type. Of these two types, no reliable results were obtained from the former but the infrared gas analysers showed a performance adequate to meet the specification. Copies of the report may be seen on application to the libraries recognised as depository libraries for Authority publications; in case of difficulty, the Industrial Group Headquarters of U.K.A.E.A. at Risley, Lancs, is prepared to consider requests for loan.

* C. D. Reid *et al.* Report No. IGR-R/CA-201 (D). U.K.A.E.A. Industrial Group.

Strengthening Soldered Joints Subject to Cyclic Loading

IT is not only car manufacturers who deal with soldered joints subject to variations in pressure and some work sponsored by this industry may help other engineers with jointing problems. As off-shoot of an investigation on the effect of cerium on soldered joints in car radiators, workers at the Battelle Memorial Institute, Columbus, have found that tin-rich solders in general give a better performance than those of low tin content under cyclic loading. Soldered joint seams were subjected to a pressure which rose from 0 to 20 pounds per square inch and then fell to zero again, six times in a minute; the steady temperature in the test was approximately 250°F. The test piece was a box of thin sheet brass, 0.018 in. thick (0.45 mm.), made from two brass pressings or capsules, one of them flanged outwards so that the other half fits within it. These soldered test boxes were mounted on the cyclic loading apparatus and subjected to the cyclic loading until failure occurred. Joints made with a solder of composition 30 Sn—70 Pb had an average of 1636 cycles to failure. When a composition 70 Sn—30 Pb was used this average rose to 4960. An addition of 0.05% of cerium to this alloy increased the figure to 11,494. A fuller account is given in the Spring, 1958, issue of "Tin and its Uses."

Fresh Drive Against Water Pollution

QUICK work by a joint committee has resulted in early adoption of a new programme for dealing with industrial wastes. In the 1957 Report of the Water Pollution Research Board, PROFESSOR F. H. GARNER referred to a recommendation that such a committee should be set up by the Laboratory and the Federation of British Industries. The first meeting was held last November. Since then priority has already been allotted to four subjects. These are the effects of trade effluents on rivers, the dewatering of sludges, sedimentation in tanks and microbiological work. Broadly the former two subjects will involve expanding current programmes; work on sedimentation has not yet started and that on microbiological work is still on a small scale. From the Water Pollution Research Laboratory we learn that there will be studies on both the inorganic sludges produced during treatment of effluents and those from sewage. The sedimentation programme will include treatment of design and materials of construction for both the tanks themselves and auxiliary equipment.

D.S.I.R. Asks for More

"WE are convinced that the Department, in its various activities, is doing work of the utmost importance and may well be needed to do more. Scientific research is not cheap, though its rewards are great. We firmly believe that the nation's research efforts must be increased, and that the Department has a large part to play". After a careful reappraisal of what it is doing and where it is going, these were the main conclusions of the Council for Scientific and Industrial Research in their report for 1956-57 (H.M. Stationery Office, price 4s.). Though the details are interesting, it is the broad pattern of their thought that is of major importance. In those industries that do not benefit directly from research done primarily for defence purposes they point out the value of production approaches £10,000 million a year. By contrast, the Department receives less than £10 million a year for all its activities.

The main theme of the report is to examine four key questions:

1. What part should the Department play in the conduct of pure research?
2. What part should its own stations play in research of direct application to industry?
3. Given the growing need for expensive team work, how should resources be allocated to avoid spreading them over too wide a field?
4. To what extent can industries served by the grant-aided research associations be expected to shoulder the whole financial burden of an adequate research programme either now or in the near future?

It is this discussion which makes the report a fresher and more important document than usual.

Heat and Power Reviews

AS a "contribution" to the Industrial Fair at Hanover, the journal "Brennstoff-Wärme-Kraft" has devoted a whole issue (April, 1958) to appraising the current state of heat and energy problems in West Germany. Introduced with appropriate weight—a paper by Ministerialrat DR. H. LAURIEN on co-ordinating gas supplies—are a total of 35 relatively short technical review papers. They deal with accessories as well as direct fuel using equipment. What are the trends in coal pulverizers, feed water treatment, heat exchangers, insulation or pipes and valves? Where are the most useful recent papers for calculating heat exchangers including discussion of condensation in presence of inert gases or partial condensation of two-component mixtures? Would you like a list of recent literature on compressors, refrigeration or drying? You will find these and more in this unusual issue.

Aluminium in Oxygen Plant Construction

In last month's issue (page 235) we published a copy of a letter addressed to Mr. Dubs, of the Union Carbide and Carbon Corporation. We have now received a copy of the reply and reproduce the pertinent sections below:—

April 9, 1958.

Mr. E. D. Verink, Jr.
Aluminum Company of America
New Kensington, Pennsylvania.

Dear Mr. Verink,

Mr. Dubs has asked me to answer the questions you had concerning his article, "Recent Developments in Industrial Oxygen Production," which you appraised from a summary published in the February issue of *British Chemical Engineering* (page 94). Since his original paper did not agree with your quotations from the summary, my answer was deferred until a copy of the summary was obtained.

The statement was made that aluminum is not preferred in applications where pressure reversals of cyclic stresses are frequent not because of the rapid fall in strength after 1000 cycles but because of the low strength of 10,000 psi after 10 million cycles. A description of the S-N curve was included to show the only difference between your data and that typical of other alloys, the plateau at less than 1000 cycles. Actually, 10,000 psi is optimistic. No alloy was specifically mentioned but your data shows that the fatigue strength of welded 6061T6 alloy is uncomfortably close to the ASME design stress and that the value of welded 5154 is below the design stress.

To be objective, it was emphasized that while great economy could be gained with aluminum construction certain welding disadvantages had to be accepted. Among these is the difficulty in obtaining good penetration, which results in the need for more back welding than with other alloys. Thus, the statement was made that good weld penetration is difficult to achieve with aluminum even on $\frac{1}{8}$ in. sheet. Another is the need for "Vee" type joints in gages over $\frac{1}{4}$ in. Steel plates may be square butt welded up to at least $\frac{3}{8}$ in.

I hope this discussion will help clear the distortion of our views.

Very truly yours,
LINDE COMPANY,
C. M. Heath.

Reprocessing Uranium by the Volatile Iodide Process

EXPERIMENTAL studies by W. L. ROBB at the Knolls Atomic Power Laboratory in U.S.A. have shown that a volatile iodide process may be used for decontaminating uranium metal or uranium alloy fuel elements. Decontamination from all long-lived radioactive fission products except zirconium was obtained by forming UI_4 and volatilizing the iodide at about 600°C, then decomposing it to deposit uranium metal on a hot wire at 1200°C to 1400°C. By selective condensation of the UI_4, separation of uranium and zirconium was effected. It was also possible to co-deposit uranium and zirconium, which might be desired in reprocessing uranium-zirconium fuel elements. Deposition of molten uranium metal on a heated ZrC cylinder and the continuous removal of the uranium from the cylinder were also investigated. The laboratory-scale work was carried out in a quartz apparatus but it was so successful that MR. ROBB carried out corrosion studies on a number of possible constructional materials and designed a pilot plant. This consists of an iodiding furnace loaded remotely under an inert gas blanket, a UI_4 condenser, a decomposition chamber for UI_4 from which molten uranium can drip and a condenser

for undecomposed UI_4 plus lower uranium iodides. There are also cold traps to collect fission products and iodine and vacuum pumps. The equipment, which must resist iodide vapours of about 300°C, would be made of tantalum or an equally resistant metal or ceramic. The report is available from the Office of Technical Services, Department of Commerce, Washington. Its reference number is KAPL-1788.

Effect of Roughness of an Orifice Plate

THE discharge coefficient of an orifice of very low *m* ratio is quite unaffected by variations in pipe-wall roughness but the orifice-plate wall friction, even for a perfectly smooth plate, can affect the coefficient by about 15%. This is the extent of the coefficient increase at Reynolds number values of about 500, and it is evident that surface roughness of the plate should also have some corresponding though smaller effect. In a recent issue of the *Instrument Engineer* (Vol. 2, No. 5, 1958, p. 91) Mr. H. E. Dall discusses this problem and reports some tests. Three types of artificial roughness were investigated. They were:

(*a*) Smooth brass plate on one side and the other machined with concentric grooves of vee section giving a gramophone finish.

(*b*) Smooth brass plate on one side, the other overlaid and in adhesion with an orifice plate of precisely equal bore punched with a specially made cutting tool from ordinary emery paper of one of two grit sizes.

(*c*) A glass orifice polished on one side, the other ground with carborundum grains against a flat iron plate. The orifice bore was fine lapped as a final operation to remove edge chippings from the coarse grit of the face grinding.

The tests were primarily comparative to give the difference of coefficient between smooth and rough surfaces, all other conditions being equal. They covered a Reynolds number (based on orifice bore) ranging from 20,000 to 230,000, and the scatter of individual points did not exceed 0.2%. The orifices were of relatively low *m* values and the discharge coefficients about 0.6.

What was the conclusion? If an augmentation of the discharge coefficient by one-tenth of the normal tolerance can be accepted for the purpose of specifying the surface finish in flow-measurement codes for orifice plates, the tests showed that the roughness should not exceed 0.03% of the orifice bore, i.e. 300 micro-in. per 1 in. bore or 3 microns per 1 cm bore.

Preventing Explosions Due to Static

EARLY in 1954 a large tank in Shell's refinery at Pernis exploded 40 minutes after the start of a blending operation. A public service has been performed by this company in now publishing the report* of their extensive investigation of this accident caused by static electricity. In a beautifully produced volume, the theoretical and practical work is described in detail up to the large-scale tests in tanks and fuelling equipment. Safety measures proposed are:—

(*a*) preventing the formation of an explosive gas mixture;

(*b*) preventing the accumulation of electricity on equipment, by earthing;

(*c*) preventing the accumulation of electricity in liquids, by the use of antistatic additives;

(*d*) reducing the generation of electricity.

In temperate climates a petroleum product with a Reid vapour pressure above 4.5 lb./sq. in. or with a flash point 15°C above the storage temperature is generally safe. In other cases formation of explosive gas mixtures can sometimes be prevented. Earthing is insufficient as a safety measure in the petroleum industry because the electric charges on oil products usually leak away slowly. Thus build up of charges must be expected when pumping, although metal parts have been earthed. This has led to work on antistatic additives to increase conductivity of petroleum distillates. A mixture of chromium AC (chromium salts of mono- and di-alkyl salicylic acid) and the calcium salt of Aerosol OT (sodium di(2-ethylhexyl) sulpho-succinate) in minute amount is effective. Finally, maximum pumping speeds have been laid down—for hydrocarbon-water mixtures, a linear velocity of 1 m/sec, for products free of a second phase up to 7 m/sec. Such are the bare bones of the recommendations. But this valuable book should be read right through, carefully, cover to cover.

* "Electrostatics in the Petroleum Industry." Ed. by A. Klinkenberg and J. L. van der Minne. Elsevier, London, 1958. 40s.

A 24-page reprint of a series of articles entitled "Liquid Atomisation in Chemical Engineering" by R. P. Fraser, O.B.E., M.I.Chem.E., P. Eisenklam, Ph.D., M.Eng.Sc., A.M.I.Chem.E., and N. Dombrowski, Ph.D., A.M.I.Chem.E., published in *British Chemical Engineering*, has been specially prepared in response to numerous requests. Copies are available from the Publishers at 4s. each, postage 2d. The appropriate remittance must accompany orders, which should be sent to The Circulation Manager, *British Chemical Engineering*, Drury House, Russell Street, London, W.C.2.

More Help for Sandwich Course Students

MANY sandwich-course students will be helped by a new circular "encouraging" Local Education Authorities to give them greater financial support. In certain cases L.E.A.'s have refused to give maintenance awards to eligible students because they thought this to be the employer's responsibility. In others, the student has suffered when his normal salary in industry exceeded the amount of an L.E.A. award. Now, the Ministry of Education and the Federation of British Industries in a joint statement, have urged both industry and the authorities to help students. They point out that industry, in giving this help, acts in its own as well as in the nation's interest. Firms which already pay their students' fees and remuneration while at college should therefore continue to do so. Those adopting sandwich courses in the future should follow this example. When the students cannot get this assistance, the Minister considers it reasonable to treat separately (for the purpose of awards) the periods spent in college and in the works. A student's earnings in industry will not normally be such that he can reasonably be expected to carry over savings from the works periods to help to support him in the college periods. The Minister is therefore advising authorities that a student's works period should ordinarily be regarded as self-contained and that unless his earnings during such periods are exceptional, having regard to his age and circumstances, they should not be taken into account in assessing any award for the college periods.

We are told by the Ministry that this is not a change in policy. In different parts of the country there have been varying methods of interpreting the regulations and the new document "Administrative Memorandum No. 567" will simply give guidance in a way that should promote recruitment of students.

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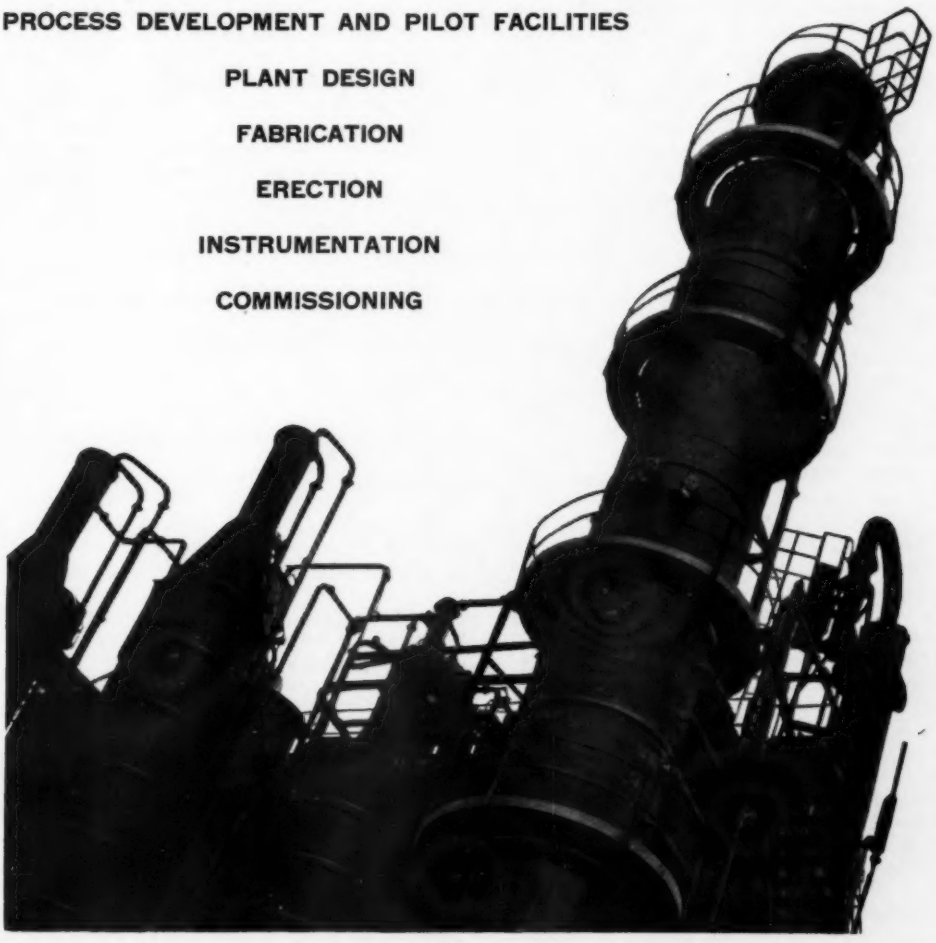

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Technology, Research and the State

THROUGHOUT history technology has been a dominant factor in the progress of mankind. It has influenced profoundly the character of society and the relationships between men. The earliest primitive technology enabled man to elevate himself from a mere collector of subsistence to its creator and the discovery of fire and metals opened the way for a steady, if not spectacular, advance in material conditions for many centuries. During this long period, technology depended upon the experiences of production until the advent of research, which then began to act as the main source of technological advance. The discoveries in physics and chemistry of the nineteenth century had such an effect upon technology that productivity leapt ahead at an unprecedented rate. Engineering itself began to take on the aspect of a highly specialised profession, whose principal objective was to make possible the transition from basic knowledge to machines, materials and techniques. As well as a high and steadily rising productivity, another outstanding feature of present-day civilisation is the narrowing gap between fundamental discovery and its commercial application. These factors have a great bearing upon the prosperity and stability of a community. The future progress of science and technology is therefore of such far-reaching national interest that it was not surprising that it was the choice of subject for the presidential address to the recent annual general meeting of the Institution of Chemical Engineers.

The detailed and objective analysis of the position of research and development in this country to which Sir Hugh Beaver devoted the major part of his address was noteworthy in a number of respects. The main aspects of the problem of advancing science, and of applying fruitfully and rapidly its discoveries, were compared with the organisations available for achieving these ends. An adequate supply of scientists and technologists, the resources of manpower and money for conducting nation-wide research, the dissemination of discoveries and their use, and the encouragement of development work were seen to be the principal parts of this formidable problem. Sir Hugh then examined the activities of the State in these various directions, and, if solvable under the existing organisational arrangements, in what direction these solutions would lie. Inevitably, attention was given to the inadequate supply of science teachers; a problem which he considered insoluble with the existing machinery. It was unmasked with brutal clarity that if there were a national education policy the means for carrying it out were not yet in existence. From a survey of the nation's capacity for making scientists and engineers, the conclusion is drawn that the output will fall far short of that necessary to maintain the rate of technological advance essential to this country, which if the present circumstances persist will be short of scientists and technicians for 20 years to come. When one tries to find the cause of this situation, an extraordinary dilution and diffuseness of responsibility are revealed.

In spite of the outstanding achievements of this country in the application of scientific discovery, the country as a whole uses the results of research tardily; there is a strong element of frustration in this for the chemical engineer who is, above all, the engineer of development. In this, his position compares unfavourably with that of his counterpart in the U.S.A., where his special role in industrial development is much more clearly understood.

Earlier, the president hinted that greater State intervention would be needed to correct shortcomings in education and in the direction of scientific work. A suggestion was made for a "Ministry of Science" whose head would have a position of command comparable with that of the Minister of Defence. This is an idea worthy of trial and, even were it to fail, from its ruins some form of organisation would emerge capable of meeting the needs of this country's technology.

State-controlled expansion of a number of organisations, as well as the creation of some new ones, seems inevitable. Expansion under the State, however, may have many pitfalls. In present-day society with its intense specialisation much of the work carried on within its boundaries must be done by corporate bodies. There are few tasks which can, in their entirety, be performed by a single individual. On the contrary, many tasks call for large numbers of people working together in an organisation. In any sizeable organisation there must be people who have the job of maintaining the proper environment for the production work to proceed. The function of these administrators is good-housekeeping, and it is one which is subordinate to the production aims of the organisation; unfortunately, administrators have a habit of gaining control over a whole body and in large organisations this risk is accentuated. Nothing worse can happen to a corporate body than the assumption of command by administrators, because the organisation becomes an end in itself and its aims a secondary matter. Since expansion of organisation there must be if science and technology are to advance, it is well that we should be aware of this particular danger.

Another hazard is that a proper balance between applied and fundamental research may not be struck. Although research devoted to specific problems is not likely to suffer from shortage of resources, there is a real danger that officialdom may take a short-term view of fundamental research and see in it merely a financial gamble and a dissipation of effort. Here it is well to remember that the utility of one of Michael Faraday's discoveries in electricity and magnetism was once questioned. Nevertheless, this same discovery led to the invention of the electric motor.

To restrict pure research, therefore, will be to throttle that flow of fruitful discoveries upon which technology thrives. The gamble will lie not in extensive facilities for pure research but in their restriction. Finally, it must be recognised that nature's secrets are becoming increasingly difficult to reveal. They require more effort, equipment and scientists.

661.5/.63; 661.31 : 631.8

THE MANUFACTURE OF GRANULATED, HIGH-ANALYSIS MIXED FERTILISERS

A process for the manufacture of high-analysis fertilisers, such as ammonium phosphate-potash mixtures, on a large scale is described in this article

by CHRISTOPHER J. PRATT, M.I.Chem.E., A.M.I.Prod.E.

THE population of America is increasing rapidly; already the 160 million mark has been passed and it is anticipated that this figure will grow to 200 million within the next 20 years. At the same time, available crop land is decreasing, for in 1920 nearly 4 acres *per capita* were available for agricultural purposes compared to a current level of about 2.5 acres. By 1970, it is said that only 1.9 acres will be available to feed each person, so that farmers will have to rely on chemical fertilisers to an increasing degree in order to produce sufficient foodstuffs for the nation. A similar situation is arising in many other parts of the world and one way of ensuring a plentiful return of nitrogen, phosphorus and potassium to the soil, with minimum transportation and application costs, is to use high-analysis fertilisers.

Fertiliser Trends

During the last 25 years, three important trends have taken place in the inorganic fertiliser industry, namely:

(1) an increase in the plant food content (N, P and K) of both unmixed and mixed fertilisers;

(2) a greater use of mixed fertilisers containing two or three of the primary nutrients N, P and K; and

(3) a rise in popularity of mixed fertilisers having a high water solubility.

These trends have been particularly evident in respect of phosphate fertilisers. For many years, phosphorus was applied to the soil largely in the form of normal or single-superphosphate, which even in 1947 accounted for some 90% of the P_2O_5 used for agricultural purposes. In 1956, however, this figure had fallen to about 62%, since 30% was supplied by triple-superphosphate and 8% by ammonium phosphates. It is anticipated that this development will continue, since single-superphosphate, which may be expressed as $CaH_4(PO_4)_2.H_2O$, contains only about 18% available P_2O_5, compared to figures in the region of 40 to 45% for triple-superphosphate ($3CaH_4(PO_4)_2$ and 50 to 60% for ammonium phosphate, in commercial form.

Mixed fertilisers, too, have increased in concentration, as is apparent from the following table[1]:

TABLE 1.—Average Percentage of Plant Food Content in Mixed Fertilisers

Year	Total %	N%	P_2O_5%	K_2O%
1920	13.9	2.3	9.2	2.4
1940	19.9	3.8	9.6	6.5
1955/56	28.7	5.4	12.1	11.2

Due to this enrichment, the amount of the primary nutrients N, P and K consumed was 1.5% higher in 1955/56 than in 1953/54, although the tonnage of mixed fertilisers used was 4.9% less. Much of this increase was due to a greater production of high-analysis fertilisers, such as ammonium phosphate (yielding about 11% N and 48% P_2O_5) and ammonium suphate-ammonium phosphate-potash mixtures, which are used to make compounds such as 12-16-16 (N-P_2O_5-K_2O) or 14-14-14.

The importance of high water solubility has been debated in the fertiliser industry for many years. There is increasing evidence to show that this property (together with particle size and placement in the soil) is a significant factor in obtaining efficient fertiliser utilisation and good crop yields.[2] This is borne out by the rising demand for water-soluble compounds such as the solid ammonium phosphates and the high-nitrogen solutions. These may be applied either alone or in conjunction with water-soluble materials containing phosphorus and potassium.

Basic Requirements

The manufacture of high-analysis mixed fertilisers can be classed as a large-scale chemical operation which is subject to the following special requirements:

The Product

(i) Versatility—wide ranges of N, P_2O_5 and K_2O in product formulations should readily be obtained.

(ii) Stability—all products should be chemically and physically stable.

(iii) Suitability—all products should be in a form entirely suitable for packing, distribution and application; for example, dust, dampness and setting-up are to be avoided.

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Deliveries of Fertilisers in the United Kingdom

July-June,	(In terms of plant nutrient content) Nitrogen, tons N	Phosphates, tons P_2O_5	Potash, tons K_2O
1938/39	59,900	170,500	75,000
1955/56	291,300	385,800	305,500
1956/57	302,000	369,600	317,700

To encourage the greater use of fertilisers, the Government pays contributions to farmers towards the cost of fertilisers purchased.

The Ministry of Agriculture, Fisheries and Food state that manufacturers in this country are well aware of the advantages of high-analysis fertilisers. Concentrated complete fertilisers in granular form, based on ammonium phosphate, have been manufactured by Imperial Chemical Industries Ltd. for many years, and Fisons Ltd. produce concentrated mixed fertilisers based on triple superphosphate.

Furthermore, in addition to the usual requirements of economy and efficiency in the process, the plant particularly needs to be designed to operate flexibly. Mixed fertilisers are seasonal specially-formulated products requiring flexibility in the plant and special attention must be given to storage facilities.

High-analysis mixed fertiliser manufacture on a large scale is limited to a very few processes throughout the world. One of these is the Dorr-Oliver complete fertiliser process, which will be described later. This company has designed many large-scale plants for making phosphoric acid and mixed fertilisers, both separately and jointly, for clients in the U.S.A., Canada, Europe, Japan and other countries.

Two Fundamental Points

In contemplating the manufacture of a "complete" fertiliser, i.e., containing predetermined amounts of all three primary nutrients nitrogen, phosphorus and potassium, two fundamental points must be considered:

(a) Upon which pivotal or main element will manufacture be based?

(b) In what form will the proposed fertilisers be made and sold?

The answer to the first question usually depends upon the tonnages to be produced. For instance, when outputs of only a hundred tons or so a week are envisaged, the plant may be little more than an ammoniator, whereby potash and superphosphate or other phosphate materials are combined with anhydrous ammonia and perhaps ammonium sulphate in some simple type of mixing-screening system. On the other hand, when outputs of several hundred tons of mixed fertiliser a day are required, it is more expedient to start from phosphate rock and sulphuric acid so as to produce phosphoric acid, which can then be used to make ammonium phosphate together with ammonium sulphate *in situ*, if required. Since anhydrous ammonia and sulphuric acid can usually be transported to a site, or made on the spot in compact plant units, large-scale mixed fertiliser manufacture tends to be

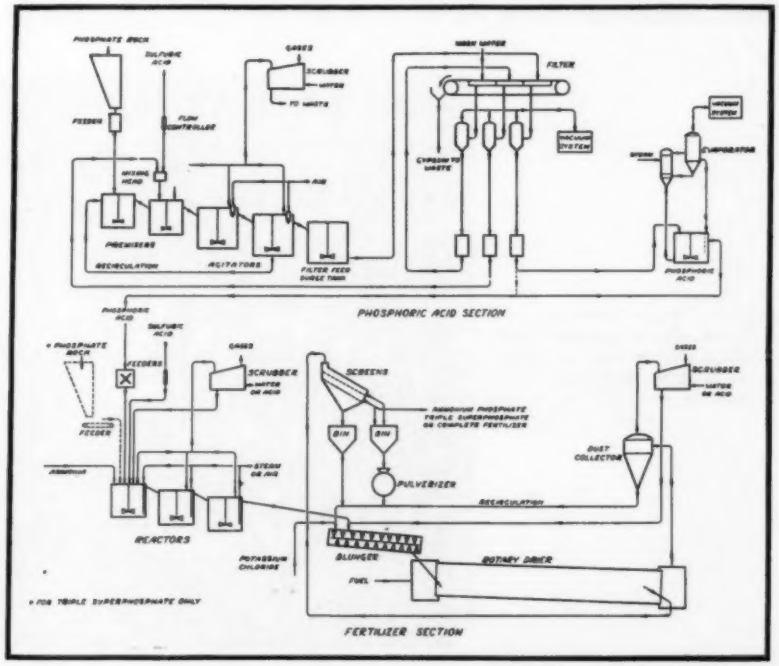

Fig. 1. The Dorr-Oliver strong phosphoric acid process (upper section). The mixed fertiliser process (lower section).

Fig. 2. A modern phosphate rock grinding system. Noticeable features are the freedom from dust and the centralised control.

centred on phosphoric acid production, which forms the key item in the process.

The form in which the mixed fertiliser will be produced depends on several factors—mostly associated with the market—such as the nature of the soil, transportation and application, price and even custom. One of the most suitable and popular forms is a granulated product, made by building successive layers of the mixture round small nuclei in onion-skin fashion to produce hard, stable granules or pellets, which can be screened to the range of diameters required. Such a material is virtually dustless, largely free from setting-up and flows easily. This aids bagging, transportation and subsequent application to the soil.

A typical plant at Joplin, Missouri, U.S.A. producing granular ammonium phosphate and complete mixed fertilisers from phosphate rock has an annual capacity of 70,000 tons of mixed fertilisers. Some of the main features are reviewed in the next section, which also shows illustrations of some of the equipment used. Similar mixed fertiliser units with capacities of several hundred tons a day are now under construction or operation in Britain and elsewhere.

The Complete Fertiliser Process

A fully integrated plant for manufacturing complete fertilisers comprises the following sections:

(1) rock unloading and grinding;
(2) phosphoric acid production;
(3) mixed fertiliser production;
(4) product storage; and
(5) bagging and shipping.

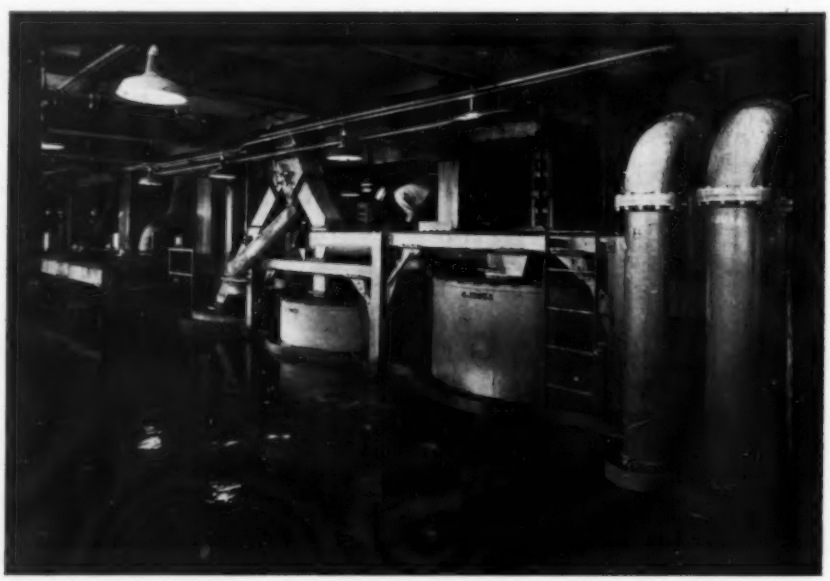

Fig. 3. The principal reaction between the tricalcium phosphate in the rock and sulphuric acid yielding phosphoric acid occurs in this section of the plant.

Fig. 4. A travelling pan filter under construction. This filter operates in simple counter-current fashion in three sections.

According to circumstances, certain ancillary sections may also be required, such as:

(6) water treatment facilities;
(7) a sulphuric acid unit;
(8) an anhydrous ammonia plant, or provisions for the bulk storage and transfer of anydrous ammonia; and
(9) effluent treatment and waste disposal.

Rock Unloading and Grinding

Phosphate rock in "pebble" form is conveniently handled from barges by grabs or on rail via hopper cars, and transfer to storage silos can be made by bucket or belt conveyor, preferably the latter. Storage silos are usually of cylindrical, concrete construction; a typical size is 30 ft in diameter by 45 to 50 ft high, equipped with a live upper section and holding about 1000 tons of unground rock.

Grinding is generally performed in a dry system; a popular form of mill is the roller-type equipped with an air-classifier, although air-swept ball mills are preferred by some plants. Ground rock is discharged from a cyclone type of separator into steel storage bins for subsequent use in the plant. When phosphate rock is used for both acid manufacture and for incorporation in fertilisers, two grades of rock may perhaps be used and these are termed the primary and secondary rock respectively. Primary rock, averaging about 68% B.P.L. (bone phosphate of lime) is ground to at least 60% passing through 200 mesh. Secondary rock, averaging 72% B.P.L. may be ground even finer —at least 75% passing through 200 mesh. At such degrees of fineness, the material readily fluidises with air. Hence a pneumatic system can be used to transfer ground rock from the main storage bins to the feeder bins in the phos-

Fig. 5. Phosphoric acid evaporation in a continuously-recirculating system. Incoming 32% acid is mixed with concentrated 55% acid.

phoric acid plant, as well as the fertiliser section if required.

A modern grinding and handling system for phosphate rock is shown in Fig. 2. Two noticeable features are the absence of dust, and centralised control.

Phosphoric Acid Production

Wet-process phosphoric acid manufacture may be conviently divided into three sections, namely: (a) reaction; (b) filtration; and (c) evaporation.

The schematic flow diagram of a widely-used process of this type is shown in the upper part of Fig. 1. An acid of 32% is produced in the reaction section, which is filtered and subsequently evaporated to concentrations up to 55%, depending on requirements.[3]

Reaction

The principal reaction occurs between tricalcium phosphate in the rock and sulphuric acid, to give phosphoric acid and insoluble calcium sulphate, i.e.;

$$Ca_3(PO_4)_2 + 3H_2SO_4 + 6H_2O = 3CaSO_4.2H_2O + 2H_3PO_4$$
$$\triangle H = -83.7 \text{ K cal. per g. mole of } Ca_3(PO_4)_2$$

Certain side reactions also take place, such as between calcium fluoride and sulphuric acid to give hydrofluoric acid and gypsum, and between hydrofluoric acid and silica in the rock, to yield hydrofluosilicic acid and water.

Two major considerations govern the operation of this apparently simple process; (i) effecting a complete reaction; and (ii) obtaining an easily filtered gypsum.

Close control of sulphate concentration, dilution, temperature and reaction time is essential for maximum conversion and optimum filtering characteristics. This makes imperative the use of accurate feeding devices for rock dust and sulphuric acid. Automatic belt-type feeders, have been used in the past for controlling the addition of rock, but continuously operating batch-type weighers are also coming into prominence for this purpose. Accurate control of sulphuric acid addition can be obtained by using a rotary scoop-type feeder, a rotameter and associated pneumatic controller, or a magnetic-flux type flow-controller.

The process is also aided and controlled more closely by providing violent agitation, ample recirculation and adequate retention, as well as sufficient cooling facilities, since the reaction is exothermic (of the order of 20 Kg cal. per 100 g of rock). These features are obtained by using a series of large tanks equipped with turbine agitators and stepped vertically (so as to permit external flow between each tank via external launders) as shown in Fig. 3. Large external pumps provide recirculation between the last tank and the first, and retention is governed by the size and number of the tanks. Cooling may be effected by means of low-pressure air blown through the slurry in each tank or, alternatively, by flashing-off steam in a vacuum cooler.

Because of severe corrosion and abrasion, operating conditions in the reaction section, as well as other parts of the plant, are extremely onerous. As a result, rubber-lined equipment has found favour for tank and pump linings, ductwork and piping. Where possible, rubber hose is also used. Because of the need for frequent descaling, major piping, pumps and other equipment are usually duplicated in order to permit frequent washing without interrupting production.

Another important feature is the provision of adequate fume removal and effective vapour scrubbing facilities. A comparatively recent development for this and similar purposes is the Doyle impingement scrubber,[4] which uses only a small volume of water, yet removes virtually all the fluorine gases and entrained solids from the reaction gases, before passing to the fume fan and stack. A typical case is the reduction of fluorine from 48 mg to 1.1 mg per cu. ft in 25,000 cu. ft per min. of gas, using between 50 and 75 gal. per min. of scrubbing water for two scrubbers in series. Other interesting applications have recently been reported,[7] indicating scrubbing liquid requirements to be between 0.5 and 2 gal. per 1000 cu. ft of gas and removal efficiencies to be between 97% and 99.6% on an inlet-weight basis.

Filtration

Reaction slurry from the last agitator is pumped to a filter station for the separation of gypsum from the phosphoric acid. This operation has had a tradition of difficulty until recent times, owing to troubles caused by corrosion, scaling and blinding. A wide variety of equipment such as drum, disc, belt and horizontal filters has been tried, many with only partial success.

A machine which was specially developed for this application is the Dorr-Oliver travelling pan filter shown in Fig. 4. Several years of operation in phosphoric acid plants in various parts of the world have proved this machine to be very suitable for this purpose. The basic operating principle is that a series of shallow filter pans is attached to an endless rubber belt, provided with appropriate drainage ports, and this travels over three suction boxes which drain to corresponding filtrate receivers, thus enabling positive separations of strong liquor, weak liquor and wash liquor to be made. Filter cake is discharged as the belt passes over the tail drum. As the belt returns in an inverted condition on the underside of the machine, each pan and filter cloth (usually Saran or stainless steel) is vigorously sprayed with water. Much of the success of these machines is attributable to this provision for ample spray washing, which helps to reduce scale formation and cloth blinding to an absolute minimum.

Operation of this filter is in simple countercurrent fashion. The machine is divided into three sections and slurry containing about 40% of gypsum is fed to each pan in turn as it passes under a distribution trough at the head of the first section. A cake several inches thick rapidly forms and phosphoric acid of about 32% P_2O_5 concentration passes into the first receiver for subsequent evaporation and use.

As each filter pan passes along the machine, the cake is washed in the second section, by filtrate from the third section. These washings collect in the second filtrate receiver as weak phosphoric acid of about 17% P_2O_5 concentration. This is pumped back to the reaction system and combined with the concentrated sulphuric acid feed in a vortex mixer immediately prior to being added to the reaction slurry. In the third section of the filter, the cake is washed with hot water, before being discharged over the tail drum of the filter and sent for disposal.

Evaporation

A mixed fertiliser plant may require evaporated phosphoric acid of about 40% to 55% P_2O_5 produced from the 32% P_2O_5 strong liquor separated in the preceding section. Due to troublesome scaling and severe corrosion, this operation has presented many difficulties in the past, but these have been virtually overcome by the use of the Dorr recirculation system.[5] Briefly, this method consists of concentrating the acid in a continuously recirculating system, in which the incoming 32% acid is mixed with the concentrated 55% (P_2O_5) acid. This causes soluble impurities

in the former to precipitate in a small external vessel, where they can be removed from the system by simple means, instead of rapidly building up in the heat exchanger and fouling the tubes.

Usually, single-effect evaporation is employed, with either parallel or series liquor feed to two or more stages and a concentration of 1 to 2% per pass is preferred. An evaporator station producing 50 to 55% phosphoric acid is shown in Fig. 5.

Evaporated phosphoric acid is stored for subsequent use in rubber-lined steel vessels. Small and medium-sized tanks are fitted with agitators to keep in suspension the small amounts of suspended solids. Storage tanks of large diameter and capacity incorporate thickener mechanisms and diaphragm slurry-pumps for the continuous removal of deposited solids.

Mixed Fertiliser Production

The range of formulations used for mixed fertiliser production is large: in 1954/55, 1750 grades were officially designated in the U.S.A. by their complete analyses. However, the U.S. Department of Agriculture lists 15 grades as representing the principal types of mixed fertiliser made.[6] For instance, the N, P and K percentages (as N, P_2O_5 and K_2O) may range from 14-14-14 to 11-48-0, or 0-20-20 in the high-analysis group, down to 5-10-5 for mixtures of lower grade.

One very suitable way of achieving the desired flexibility is to use a system in which phosphoric acid and/or sulphuric acid can react with anhydrous ammonia to produce a variety of products ranging from all-mono or di-ammonium phosphate, to all-ammonium sulphate. Potassium chloride, plus a suitable filler if necessary, can be added at a later stage to produce the required grade of complete fertiliser. Such a system, which not only enables a whole mixed fertiliser range to be made, but gives a dried and screened product as well, is shown in the lower part of Fig. 2. It consists essentially of two parts—a wet section and a dry section.

In the wet section, anhydrous ammonia, evaporated phosphoric acid and perhaps sulphuric acid are violently mixed with the reaction slurry in a two- or three-tank agitation system similar to that used in the phosphoric acid section. Usually, however, slurry recirculation is not installed and brick-lined agitators are employed. The reaction is strongly exothermic and the heat released is used to evaporate water from the products to yield a thick slurry containing about 80% solids. Any free ammonia in the escaping water vapour is recovered in Doyle impingement scrubbers, using either water or sulphuric acid, and the product is returned to the system.

The basic equations for the ammonium phosphate/sulphate reactions utilised may be written as follows:

For mono-ammonium phosphate:

$$\text{(i) } H_3PO_4 + NH_3 = (NH_4)H_2PO_4$$
$$\triangle H = -29.5 \text{ kg. cal. per g mole}$$

For di-ammonium phosphate:

$$\text{(ii) } H_3PO_4 + 2NH_3 = (NH_4)_2HPO_4$$
$$\triangle H = -47.8 \text{ kg. cal. per g mole}$$

For ammonium sulphate:

$$\text{(iii) } H_2SO_4 + 2NH_3 = (NH_4)_2SO_4$$
$$\triangle H = -65.9 \text{ kg. cal. per g mole}$$

The actual heat release in practice has to be calculated on the basis of the mono and/or di-ammonium phosphate and ammonium sulphate ratios selected, depending upon the grade of mixed product required. A plant making 250

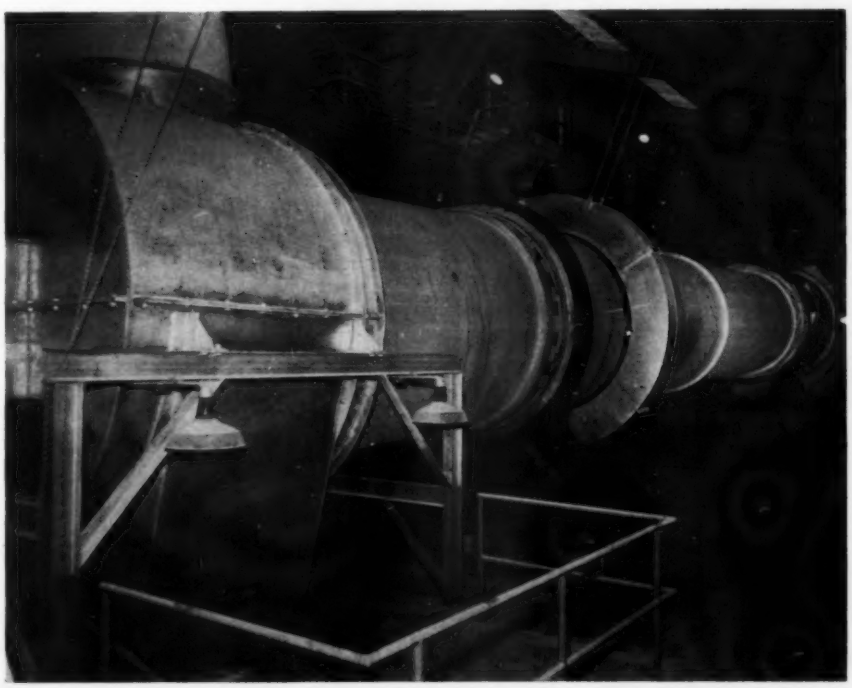

Fig. 6. A directly-heated co-current drier for granulated fertiliser production. Granules discharged from the drier are passed to the screens.

Fig. 7. A milk of lime unit for treating effluent from a large fertiliser plant.

tons a day of mono-ammonium phosphate-sulphate salts, for example, might evaporate directly in the reactors some 125 tons of water a day, by means of the heats of reaction available. This represents a considerable saving in terms of capital equipment and fuel that would otherwise be needed.

When making the mono salt only, the ammonia present in the steam from the reactors is negligible and water may be used to scrub the reaction gases. When the phosphoric acid is ammoniated further, the use of dilute sulphuric acid in the scrubber is preferred, in order to recover the small amount of ammonia evolved. This is generally less than 1% of the total used.

This process has the added advantage of enabling di-ammonium phosphate to be made directly from wet-process phosphoric acid—a hitherto difficult operation, because of impurities such as the hydroxides of iron and alumina which interfere with crystallisation. The reaction is allowed to proceed in two stages. Mono-ammonium phosphate is initially produced in the first reactor at 210°F and this is further ammoniated in the second reactor at 212°F to yield a product containing about 80% di-ammonium phosphate. Even at the high temperatures involved ammonia losses are low, because the design and method of operation employed enable a low partial pressure of ammonia to be maintained throughout the entire reaction. Two other important advantages also arise from this process. No filtration of the slurry is necessary, nor is an evaporator required, since the remaining water can be removed at a later stage in a conventional rotary drier. Furthermore, certain grades can even be made directly from 32% P_2O_5 acid without the need for further concentration.

In the dry section of the plant, reaction slurry is mixed with recycled fines, and potassium chloride if required, together with fillers or other materials—for example, gypsum, silica or perhaps minerals containing trace elements such as manganese or boron. A special type of granulator-mixer known as a blunger is used for this purpose. In this machine, small, solid particles are coated with reaction slurry prior to being dried, screened and recycled. This mixing and coating is performed by two sets of intermeshing flights mounted on heavy shafts, as in

a pug mill, and the coated particles are discharged by gravity-flow into a rotary drier. Close control of drying conditions is necessary in order to avoid decomposition and ammonia loss. A directly-heated, co-current drier is generally used and special attention must be paid to the internal design, so as to provide an even heat-transfer with minimum losses from decomposition and dust. A typical drier for this purpose is shown in Fig. 6. This has a drum 8 ft in diameter by 72 ft long. The inlet and outlet temperatures employed depend upon the product made. The moisture in the feed to the drier may be of the order of 3 to 4% and the dried particles usually contain less than 1% free moisture when discharged at temperatures in the region of 100°C.

Granules discharged from the drier are elevated to a screen room, where a three-way separation is made on inclined vibrating screens. A size-fraction between 5 and 10 mesh, for instance, is separated as the product. Particles below this size are returned via a conveyor to the blunger, while agglomerates and granules above this range are sent to a continuous pulveriser for reduction to fines, before being also sent to the blunger to form fresh nuclei.

A high recycle ratio is frequently used in this process, which may range from 5 to 6 to 1, up to 15 or 20 to 1, depending on the product. This is indicative of the flexibility which must be built into plants of this type. Ample surge capacities for oversize, undersize and product are ensured by providing bins of adequate size in each case. Dust is removed from strategic parts of the system, such as elevator heads, the drier and screens, and is recovered in multi-unit cyclones. Being before passed to the stack, exhaust gases pass through Doyle impingement scrubbers to remove the last traces of dust and fume, so that both inside and outside the plant ambient conditions are not unpleasant. Granules are discharged continuously from the product bin via a suitable control valve to a storage conveyor which usually incorporates a belt weigher-totaliser. This enables a continuous record of production to be obtained before the material passes to the storage building.

Product Storage and Dispatch

One of the major advantages of granulated mixtures produced by this process is that no subsequent pile-curing to effect complete reaction is required. However, unless sufficient consideration has been given to the design and size of the storage building, much of the flexibility built into the plant may be lost. Hence, a suitable number of bays in proportion to the number of grades produced should be provided, and each bay should have an adequate capacity, based upon such factors as seasonal demands and the production programme.

Considerable attention must also be paid to materials handling. One suitable method of transfer from storage conveyor to the various bins is to use a shuttle conveyor with a mobile discharge head. Transfer from any storage bay may be conveniently performed by scoop-trucks, which have the added advantage of providing some simple proportioning according to the number of bucket loads, when mixing of certain grades is desired. In addition, the mechanical action is useful, should incipient setting-up of certain grades occur after prolonged storage.

In order to ensure a product of uniform size and to provide some final, simple mixing if required, it is usual to install a screening-grinding system for the product before bagging and shipping. This can be located either in the storage building or the bagging department, preferably the former. Oversize and agglomerates which may have formed to a small degree in storage are broken down in a cage mill and undersize may be fed back to the blunger via the undersize bin, if desired. Sweeteners, such as hydrated lime, or special additives such as micro-nutrients, can be added at this point if required by the customer. It is equally important to organise the bagging and shipping sections on a flexible basis.

Ancillary Units

Water may be required for steam generation, reaction and process requirements, vapour condensation, wash-down and domestic uses. On some fertiliser plants units are provided to supply or recover water for the various purposes. In addition some large fertiliser plants include contact-type sulphuric-acid units of 600 to 700 tons daily capacity.

Waste disposal may also require some auxiliary plant, since it is unlikely that effluent can be discharged without treatment unless the main plant is close to the sea. Usually the problem is twofold. Acids in the effluent must be neutralised and solids, principally gypsum, and fluosilicates must be removed. Neutralisation can be effected by treatment with lime slurry, and waste gypsum can readily be settled out in ponds or lagoons, provided sufficient space is available. In some cases, lime treatment is carried out on effluent prior to settling and, in others, it has been found more suitable to neutralise the clear liquor obtained from the settling ponds, before releasing to the nearby stream or sewer. In either case, *p*H control, both by laboratory means and by automatic instruments, is used to govern the correct addition of lime slurry. A milk of lime unit for treating effluent from a large fertiliser plant is illustrated in Fig. 7.

A few plants have been designed to manufacture ammonium sulphate from the waste gypsum produced in phosphoric acid plants. The gypsum is specially washed to remove impurities and reacted with ammonium carbonate in a continuous system; the ammonium sulphate solution produced is filtered to remove calcium carbonate, evaporated and the crystalline ammonium sulphate dried and sold. It is possible that in some areas of the world this process will become increasingly attractive, as the interest in complete fertilisers manufacture continues to grow. At least one plant was designed to make calcium nitrate from the spent chalk produced in an ammonium sulphate unit of this type. However, such processes do not eliminate the necessity for proper waste treatment.

Finally, the importance of reliable instrumentation and control cannot be emphasised too strongly if minimum operating costs and proper quality control are to be attained.

Conclusion

For the latest period available in America (1955/56), the total primary nutrient-content of mixed fertilisers was 4,236,698 tons, which was slightly less than the previous year but showed a 1.5% increase over the 1953/54 period. As was indicated in the introductory part of this article, over the space of years this figure must continue to increase in order to keep pace with the rising population.

Complete fertilisers will play an essential part in supplying these demands. It is fortunate that modern chemical engineering is able to meet the challenges arising from the tremendous tonnages and technical complexities involved, thereby making a vital contribution to future food supplies.

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A NEW MILL FOR FISH MEAL

An improved technique of raw material size reduction in the cattle feeding industry is described

by K. SUCHOWSKI

THE manufacture of high-grade fish meal is not normally regarded as a field for chemical engineering techniques. Nevertheless, a number of well-recognised unit operations are employed in its production and resistance to corrosion is demanded of this processing equipment. Many plants employ standard machinery for carrying out the various processes, but there has been a distinct trend recently to the use of machinery specially designed for this particular process.

Grinding is one of the unit operations which figures prominently in the manufacture of fish meal and a number of designs of mill have been evolved to deal with the special problems of the fish meal industry. One process for converting raw fish to fish oil, good grade fish meal and other by-products is shown in Fig. 1. It will be seen that there are three separate milling operations. In each case the mill has been designed for the particular feed.

The distintegration of the raw fish is the first stage requiring a milling machine. A new design of machine will accept, depending upon its size, raw fish or pieces of fish up to 40 lb. weight regardless of bone, water or salt content. The design is such that it will reduce very tough, rubber-like skin to small uniform-sized pieces of about 1-2 cu. in. One important consequence of this size reduction, which represents a considerable improvement upon the performance of more conventional machines, is the steam saving it brings about at the boiling operation. The actual saving in steam consumption can be as high as about 10%. At the same time, the yield of fish oil and other soluble products is increased and an improved quality fish meal is obtained.

The second milling stage is used for breaking up the press cake. The latter contains as much as 50% to 60% liquid matter and this calls for special attention to the mill design in view of the tendency of material of this kind to clog the mill. The type of mill shown in Fig. 2 has been specially evolved for this kind of disintegration and

Mr. Suchowski, *who recently supervised the construction of the North German starch works, is responsible for the development of size reduction machinery for the Hazemag Organisation.*

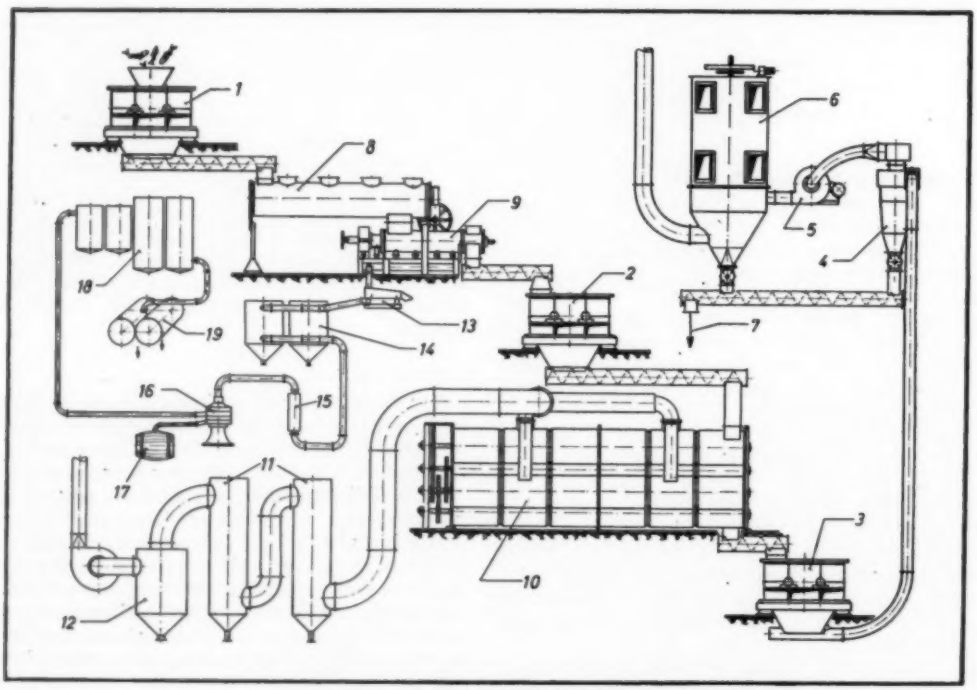

Fig. 1. Process system for the conversion of raw fish.

1. Mill for raw fish.
2. Press cake mill.
3. Mill for prepared meal.
4. Cyclone separator.
5. Exhauster.
6. Automatic bag filter.
7. Material outlet.
8. Boiler 9. Press.
10. Dryer.
11. Condensers.
12. Moisture separators.
13. Sieve.
14. Oil pre-cleaner.
15. Pre-heater.
16. Centrifuge.
17. Fish-oil.
18. Steam washer.
19. Drum dryer.

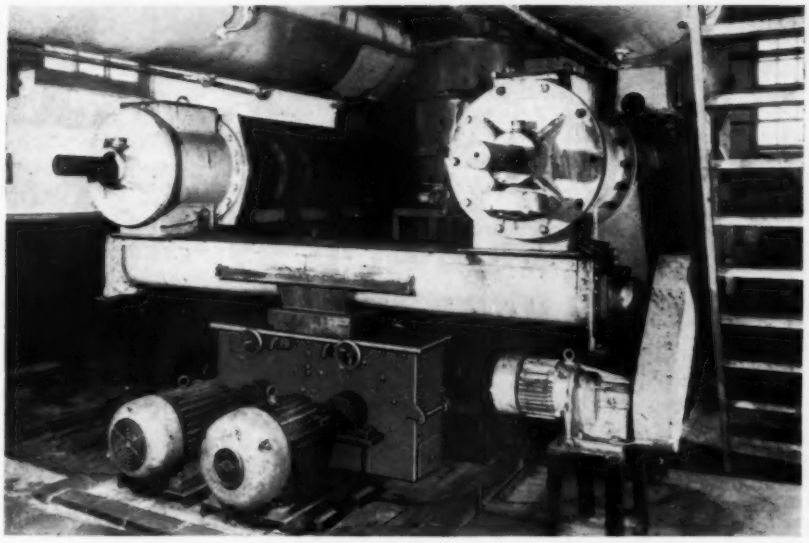

Fig. 2. A specially designed swing-hammer mill for the reduction of press cake in the fish meal industry.

it will be noted that two motors are used on this mill. A direct consequence of the size reduction of the press cake is a 10% reduction in fuel consumption at the driers as compared with driers handling a cake milled to normal standards. Other advantages arising from this particular design of mill are the degree of mixing it imparts to the material it processes and its capacity to deal with press cake to which liquid material has been added.

The third milling stage where this type of mill is being successfully employed is the disintegration of the fish meal leaving the drier (Fig. 1). The liquid content normally is as high as 12% to 14%, depending on protein and fat content, but the meal may be ground to any degree of fineness required by the trade. The mill at this stage is equipped with a pneumatic device which ensures that all the material leaving the mill is of the required state of subdivision; the ground material is then collected by means of high-efficiency cyclones and sock filters. A typical design of mill for the third stage is shown in Fig. 3; it is able to grind fish meal containing 20% of fat and water when cold and can deal with 15% to 17% of these ingredients when warm. A large number of these mills are now being supplied to the fish meal industry and figures for average power consumption obtained from many thousands of hours of operation are available. Thus, in the case of cold meal, specific power consumption is about 16 kWh per ton, while warm meal requires about 24 kWh per ton of finished product.

A valuable feature of the mill (known as the Novorotor) is that it is built to accept tramp materials which, in spite of magnetic separators and other precautionary methods, often cause serious breakdowns and damage to more conventional grinding mills. The mill is of the swing-hammer variety which can readily be adapted to suit requirements depending on the use to which the meal is to be put. Twin rotors are employed, since certain operations can only be carried out by the use of two rotors. With this machine, for example, the reduction of large elastic lumps can readily be carried out without any accessories such as screens or knives. This design is produced in a range of sizes with outputs varying from 1½ to 10 tons per hour. The basic design is the same for all types of feed, but the interior equipment can be changed according to the type of work to be performed.

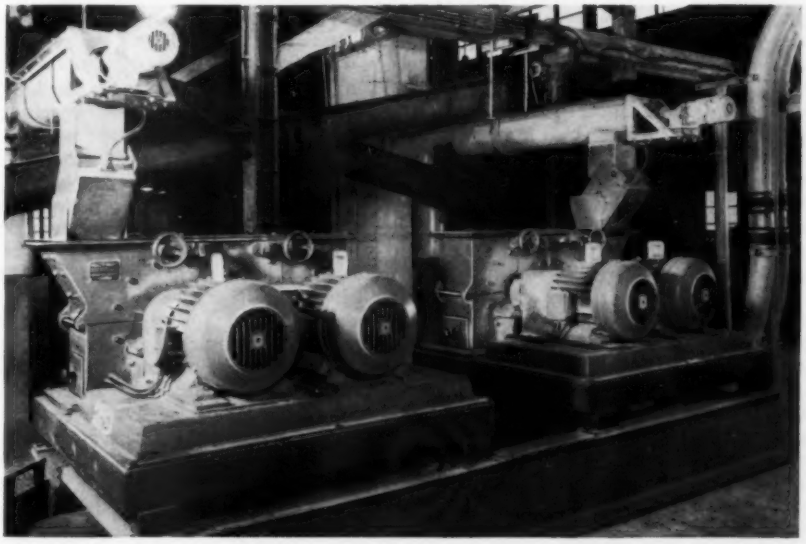

Fig. 3. Two mills similar to that shown in Fig. 2 for grinding dry fish meal.

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THE CONVERSION STAGE IN THE MANUFACTURE OF SULPHURIC ACID BY THE CONTACT PROCESS – PART II*

The authors discuss the conditions for operating the conversion stage and converter design

by G. C. LOWRISON, B.Sc., A.M.I.Chem.E., and F. HEPPENSTALL

The Mechanism of Catalysis

For a reaction to proceed it must be accompanied by either a negative or a small positive-free energy change. The individual reacting molecules must also possess sufficient energy for the complex formed temporarily by their collision to disintegrate into the required products.

In other words, the molecules themselves must possess a certain energy of activation. This energy of activation is not possessed equally by all molecules in the system, but is distributed in accordance with the theories of probability in a Gaussian manner. Therefore, although a reaction may result in a positive-free energy change it may not possess enough individual molecules with the necessary energy of activation for the reaction to proceed to a measurable extent at a particular temperature. As the temperature of the system is raised it is usual for the number of molecules possessing at least this required energy of activation to increase; but if the reaction is itself not favoured by an increase in temperature it might well be that as the temperature is approached at which the required number of activated molecules are produced, the required product is unstable.

A catalyst provides a site on which the reacting molecules may meet suitably orientated so that the required energy of activation is much less and, therefore, the reaction can proceed at a much lower temperature. The extraordinary thing, however, about solid catalysts, is that the whole surface of the catalyst is not equally helpful to reaction and, in fact, the portion of the surface which is effectively being used for the reaction is very small; it might well be 5% or 10% of the whole surface or even smaller. This observation led to the theory of H. S. Taylor that the surfaces of the solids of high chemical activity possessed certain "active centres". These active centres have been associated with the heterogeneity of the crystalline surface.

Poisoning is thus the effect of occupying these active centres at the expense of the desired reactants. This theory explains the method by which a small quantity of poison can make ineffective a large quantity of catalyst. This theory also explains the fact that there is a minimum temperature variously called the kindling, ignition or biting temperature of the catalyst, below which the catalyst will not function. For platinum this is usually considered to be 380°C and for uvanadim catalysts 415°C. This is the minimum temperature at which an appreciable number of reacting molecules possess sufficient energy to form the compound or "chemisorbed complex" as it has been called. The catalytic effect is thus seen to be closely related to the surface of the catalyst exposed to the reactants.

In the particular case of vanadium catalysts, however, the matter is more complicated because the catalysts are said to be in the liquid state when in use. However, the greater immunity of vanadium catalysts to poisons might be associated with this fact. That this catalytic reaction is closely associated with surface is supported by the fact that all conditions which rise to the exposure of greater surface, or the greater contact between the individual molecules of the substances, and of the surface of the catalyst improve the rate of reaction.

We will first deal with the effect of size and shape of the catalyst mass. As has been stated by Adadurov and Gemet, the size and shape of the catalyst mass determines:

(1) the ratio of the volume of contact space per unit mass of catalyst;
(2) the contact surface;
(3) the pressure drop of the system; and
(4) the degree of erosion of the mass.

Both the void volume and the contact surface are closely allied with the geometrical shape of the catalyst pellets. A tetrahedron has the largest surface per unit volume and a sphere has the smallest surface per unit volume; a cube is the intermediate between these two shapes. However, there is another factor which must be borne in mind and that is the degree of overlapping of the shapes when they are assembled in bulk. Both the tetrahedron and the cube have much overlapping. It is usual to compromise from the point of view of ease of manufacture and maximum surface per unit volume with a cylindrical shape. Hollow rings have been tried, but it has been found very difficult to obtain these with sufficient mechanical strength.

With regard to the mass transfer of the reacting gas to the surface of the catalyst, this is achieved in proportion to its turbulence; that is to say, it is related to the velocity of flow of the gas. However, this effect is counteracted by the reduced contact time between the gas and the catalyst and therefore there is an optimum flow limit corresponding with a certain gas concentration. In addition to this problem of mass transfer, there is the one of heat transfer with which, of course, it is mathematically closely related. It is essential that the temperature of the catalyst mass shall be kept to a minimum, otherwise

* *Part 1 was published in the May, 1958, issue of* British Chemical Engineering, *p.* 252.

the equilibrium conditions achieved on the surface of the catalyst will be less favourable than those that are obtained in the body of the gas.

Greater exposure of catalyst surface can be obtained if the pellets are not in contact, that is to say, they are fluidised; certain experiments have recently been reported in which it is stated that between three and four times the reaction rate is obtained with a fluidised bed compared with a confined bed.

Catalyst Placing

The approach to the problem of catalyst placing can be made along the lines suggested by Hougan and Watson. If r is the rate of reaction in moles converted per gram of catalyst a second, W the weight of catalyst in grams, F the feed rate in grams a second and x the moles converted per gram of mixture fed, then: $rdW = Fdx$

$$\text{and } W = F\int\frac{1}{r}dx.$$

The weight of catalyst can therefore be determined by plotting the reciprocal of the rate of the reaction against the conversion and determining the area under this graph between the limits of conversion being considered.

Calderbank has, by adsorption studies, shown that the rate of the forward reaction

$$SO_2 + \tfrac{1}{2}O_2 \leftrightarrows SO_3$$

$$\text{is } r_1 = K_1 \,.\, P_{SO_2}{}^{\frac{1}{2}} \,.\, P_{O_2}$$

where P is partial pressure of component given in subscript.

If r_2 is the velocity of the reverse reaction, then at equilibrium $r_1 = r_2$ and if r_2 is written in the form

$$r_2 = K_2 \,.\, [Y]$$

$$\text{then} \quad K_1 \,.\, P_{SO_2}{}^{\frac{1}{2}} \,.\, P_{O_2} = K_2 \,.\, [Y]$$

$$\text{and } \therefore \frac{K_1}{K_2} = \frac{[Y]}{P_{SO_2}{}^{\frac{1}{2}} \,.\, P_{O_2}};$$

$$\text{but} \quad \frac{K_1}{K_2} = K, \text{ the equilibrium constant}$$

$$\text{and} \quad K = \frac{[SO_3]}{[SO_2] \,.\, [O_2]^{\frac{1}{2}}}$$

But the partial pressures are proportional to the molar concentrations

$$\therefore [Y] = \frac{[SO_3]\ \ [O_2]^{\frac{1}{2}}}{[SO_2]^{\frac{1}{2}}}$$

$$\therefore r_2 = \frac{K_2\,[SO_3]\,[O_2]^{\frac{1}{2}}}{[SO_2]^{\frac{1}{2}}}$$

By plotting the values of K_1 against $\frac{1}{T}$ in accordance with Equation (3), the enthalpy change (heat of reaction) is determined from the slope of the graph. Calderbank found ΔH to be 31,000 cal.

and the equation to be

$$\log_e K_1 = \frac{-31{,}000}{RT} + 12.07 \qquad \ldots.(5)$$

and from Equation (2) $\log_e K_p = \log_e K_1 - \log_e K_2$

$$= \frac{22{,}600}{RT} - 10.68$$

$$\therefore \log_e K_2 = \frac{-53{,}600}{RT} + 22.75 \qquad \ldots.(6)$$

Now the rate of the reaction $r = r_1 - r_2$

$$\text{or } r = K_1 \,.\, P_{SO_2}{}^{\frac{1}{2}} \,.\, P_{O_2} - K_2 \,.\, \frac{P_{SO_3} \,.\, P_{O_2}{}^{\frac{1}{2}}}{P_{SO_3}{}^{\frac{1}{2}}}$$

Values of r have been calculated for the 4 stage conversion of 8% SO_2 gas of sulphur origin assuming equilibrium and the values obtained are shown in the following table:

Temp., °C	Conversion %	log. K_1	log. K_2	K_1/K_2	$x10^7$ r_1	$x10^7$ r_2	$x10^7$ r
Rate of Reaction 8% (Sulphur) SO_2 Gas							
First Stage							
415	0	−10.57	−16.52	346.7	9.55	0	9.55
418	1.0	−10.48	−16.23	316.2	10.3	0.00036	10.3
420	2.0	−10.41	−16.11	298.5	11.0	0.0021	11.0
422	3.0	−10.34	−16.01	288.4	11.7	0.0035	11.7
426	5.0	−10.22	−15.80	263.0	13.09	0.007	13.08
438	10.0	−9.85	−15.15	199.5	18.11	0.029	18.08
450	15.0	−9.47	−14.52	154.9	25.5	0.084	25.4
462	20.0	−9.12	−13.90	119.1	33.9	0.22	33.7
474	25.6	−8.78	−13.31	92.68	45.7	0.50	45.2
488	31.2	−8.40	−12.64	69.18	61.7	1.23	60.5
501	36.8	−8.06	−12.05	53.7	83.2	2.81	80.4
513	42.4	−7.75	−11.52	43.65	109.6	5.56	104.0
526	48.0	−7.43	−10.95	33.11	144.5	11.50	133.0
539	53.6	−7.11	−10.42	27.54	177.8	22.9	154.9
553	59.2	−6.78	−9.86	21.70	224.0	46.8	175.0
565	64.8	−6.52	−9.39	17.78	266.0	86.1	180.0
578	70.4	−6.23	−8.90	14.45	320.0	167.9	152.0
587	74.0	−6.05	−8.57	12.45	363.0	253.0	110.0
589	75.0	−6.00	−8.50	12.16	367.3	284.4	82.9
590	75.5	−5.98	−8.46	12.02	371.0	298.0	73.0
591	76.0	−5.96	−8.42	11.75	374.1	314.0	60.1
Second Stage							
415	76.6	−10.57	−16.42	345.9	3.67	0.11	3.56
420	78.7	−10.41	−16.14	306.9	4.07	0.15	3.92
425	80.8	−10.24	−15.85	271.6	4.55	0.22	4.33
430	82.9	−10.09	−15.57	238.8	5.01	0.32	4.69
435	85.0	−9.94	−15.31	213.8	5.49	0.45	5.04
441	87.1	−9.75	−14.99	187.5	6.03	0.68	5.35
446	89.2	−9.60	−14.73	168.3	6.31	0.98	5.33
451	91.3	−9.45	−14.47	155.2	6.61	1.45	5.16
454	92.5	−9.35	−14.32	143.2	6.61	1.84	4.77
456	93.4	−9.30	−14.20	134.0	6.55	2.23	4.32
459	94.5	−9.23	−14.07	126.5	6.40	2.79	3.61
461	95.4	−9.15	−13.96	122.5	6.31	3.45	2.84
464	97.0	−9.07	−13.80	112.7	5.48	5.07	0.41
Third Stage							
415	97.4	−10.57	−16.42	346.7	1.135	0.400	0.732
416	97.8	−10.54	−16.35	333.4	1.064	0.471	0.593
417	98.2	−10.51	−16.31	330.4	0.991	0.547	0.444
417.5	98.5	−10.49	−16.26	320.6	0.929	0.619	0.310
418	98.7	−10.48	−16.23	314.1	0.900	0.670	0.270
418.5	98.8	−10.46	−16.20	312.6	0.859	0.736	0.123
Fourth Stage Negligible improved conversion can be achieved in a fourth stage.							

The following show some of the actual distributions which have been used in practice using vanadium catalyst.

Type of Converter External Heat Exchange	% of Total Mass				Catalyst in litres per ton of acid per day
	First Pass	Second Pass	Third Pass	Fourth Pass	
Single Stage ...	100	—	—	—	—
Two Stage ...	30	70	—	—	180
Three Stage ...	17	24	59	—	—
Four Stage ...	16	27	27	30	180
	22.3	22.3	22.3	33.1	180
	22	25	25	28	180

Type of Converter Internal Heat Exchange	% of Total Mass			Catalyst in litres per ton of acid per day
	First Pass	Second Pass	Third Pass	
Single Stage ...	100	—	—	216
Two Stage ...	25	75	—	225
Three Stage ...	13	27	60	230
	23.6	20.6	55.8	206
	23.2	20.8	56	206
	16	23	61	268

Stage	1	2	3	4
Relative Wt. of catalyst ...	0.02043	0.06765	0.04334	Negligible
% Wt.	15.6	51.4	33.0	—

Those calculated for the 8% gas are as given above:

However, the above apply when equilibrium is achieved in each pass and, as Fig. 8 shows, the graph passes through minima for $\frac{1}{r}$ which are, of course, maxima for r.

More efficient use of catalyst can be made if the conversion does not exceed that corresponding with the maximum rate. For these conditions the placing is as follows:

Stage	1	2	3	4
Relative Wt. of catalyst ...	0.02043	0.0295	0.066	0.0541
% Wt.	12.0	17.3	38.9	31.8

Maximum utilisation of catalyst is achieved by operating continuously at maximum velocities of reaction. Maximum velocity of reaction exists when

$$\frac{dr}{dT} = 0.$$

$$\text{Now } r = r_1 - r_2 = \frac{K_1 \cdot P_{O_2} \cdot P_{SO_2}}{P \cdot {}_{SO_2}{}^{\frac{1}{2}}} - \frac{K_2 \cdot P_{SO_2} \cdot P_{O_2}{}^{\frac{1}{2}}}{P_{SO_2}{}^{\frac{1}{2}}}$$

but both K_1 and K_2 are exponential functions as given in Equations (5) and (6)

$$\text{Let } K_1 = e^{f(T)} \text{ and } K_2 = e^{f_2(T)}$$

$$\text{Then } \frac{dr}{dT} = \frac{f_1{}^1(T) \cdot K_1 \cdot P_{O_2} \cdot P_{SO_2}}{P_{SO_2}{}^{\frac{1}{2}}} - \frac{f_2{}^1(T) \cdot K_2 \cdot P_{SO_2} \cdot P_{O_2}{}^{\frac{1}{2}}}{P_{SO_2}{}^{\frac{1}{2}}}$$

where $f^1(T)$ indicates the differential derivative of $f(T)$.

$$\text{When } \frac{dr}{dT} = 0 \quad \frac{f_1{}^1(T) \cdot K_1}{f_2{}^1(T) \cdot K_2} = \frac{P_{SO_2}}{P_{SO_2} \cdot P_{O_2}{}^{\frac{1}{2}}} \quad \ldots . (7)$$

From Equations (5) and (6) it is clear that

$$\frac{f_1{}^1(T)}{f_2{}^1(T)} = \frac{-31{,}000}{RT^2} \cdot \frac{RT^2}{-53{,}600} = \frac{1}{1.73} \quad \ldots . (8)$$

Therefore from Equation (8)

$$\frac{K_1}{K_2} = \frac{1.73 \cdot P_{SO_2}}{P_{SO_2} \cdot P_{O_2}{}^{\frac{1}{2}}}$$

But $\frac{K_1}{K_2} = [K_p]_2$ the equilibrium constant at say a temperature T_2.

Whilst $\frac{P_{SO_2}}{P_{SO_2} \cdot P_{O_2}{}^{\frac{1}{2}}} = [K_p]_1$, the equilibrium constant corresponding with this degree of conversion, say T_1;

$$\text{Then } \frac{K_1}{K_2} = [K_p]_2 = 1.73\ [K_p]_1$$

Now from Equation (2)

$$\log_e K_p = \frac{22{,}600}{RT} - 10.68$$

$$\therefore 2.303 \log_{10} \frac{[K_p]_2}{[K_p]_1} = \frac{22{,}600}{R} \left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

$$= 2.303 \log_{10} (1.73). = 0.548.$$

Now $R = 1.99$ cal.

$$\text{and } \frac{0.548 \times 1.99}{22{,}600} = \frac{1}{T_2} - \frac{1}{T_1} = 0.483 \times 10^{-4}$$

$$\text{or } \frac{T_1 - T_2}{T_2 T_1} = 0.483 \times 10^{-4}$$

$$\text{Whence } T_1 = 0.483 \times 10^{-4} T_2 T_1 + T_2$$

$$\text{or } T_2 = \frac{T_1}{1 + 0.483 \times 10^{-4} T_1}$$

Thus, in order to achieve maximum velocity the mixture should be kept at a temperature less than that corresponding with its equilibrium temperature in accordance with the above equation.

Ideally, therefore, the mixture of low conversion should be fed into the converter at a high temperature and the temperature gradually decreased as conversion proceeds in accordance with the above equation. Certain internal heat exchange converters have attempted to follow this principle and will be described later.

Converter Design

In the early days of converter design very little consideration appears to have been given to the thermal aspects of the reaction. Converters, by comparison with those of the present day, were small and radiation losses must have been considerable, possibly with advantage to the conversion efficiency.

One of the earlier known types of converter was the Schroeder Grillo which consisted of a cast-iron cylinder containing five layers of platinised magnesium sulphate catalyst supported on cast-iron grids.

In the original Grillo converter the SO_2 entered at the top, and passed through the various layers of catalyst. No attempt was made to use the heat of reaction, and it was necessary to preheat the incoming gases to the desired ignition temperature in an external furnace (see Fig. 9 (a)). In a later development an annular space was added around the shell. The SO_2 gas enters the annular space tangentially at the bottom and is forced by means of baffles to take a spiral course upwards, absorbing heat from the hot gases inside the shell, thus giving some degree of temperature control (see Fig. 9 (b)). In this converter better gas distribution was obtained by downflow which reduced the possibility of channelling, and by the installation of baffle plates between the layers of catalyst. The dimensions of the inner cylinder were approximately 6 ft 6 in. inside diameter and 12 ft high. A converter of these dimensions would contain 2000 to 2500 lb. of mass on each shelf with a platinum content of 0.31%. Such a converter would have a capacity of approximately 25 tons H_2SO_4 a day, conversion efficiencies of 92% to 95% being obtained.

Another early type of converter was that employed in the Mannheim system which is the only system using a two-stage converter with different catalytic materials. The primary conversion took place in a steel brick-lined chamber called an oxide shaft which received the gases direct from the burners. The shaft was charged with burnt iron ore of particle size not less than 1 in. Each 24 hours a proportion of the ore was removed from the bottom of the shaft and replaced with freshly burnt ore, the normal depth of oxide being 8 to 10 ft. The gases entered at a temperature of approximately 700°C. After leaving this section the gases were cooled, the SO_3 absorbed in concentrated H_2SO_4 and the residual gases after preheating to ignition temperature passed into the second stage, consisting of a shaft containing platinised asbestos catalyst. Iron oxide is relatively inactive at temperatures below 600°C, and whilst theoretically a conversion of 60% was possible in the oxide shaft, in practice this seldom exceeded 40%.

One of the early attempts to utilise the heat of reaction to preheat the cold SO_2 and at the same time give some measure of control over the catalyst temperature and improve the conversion would appear to be the Badische system, details of

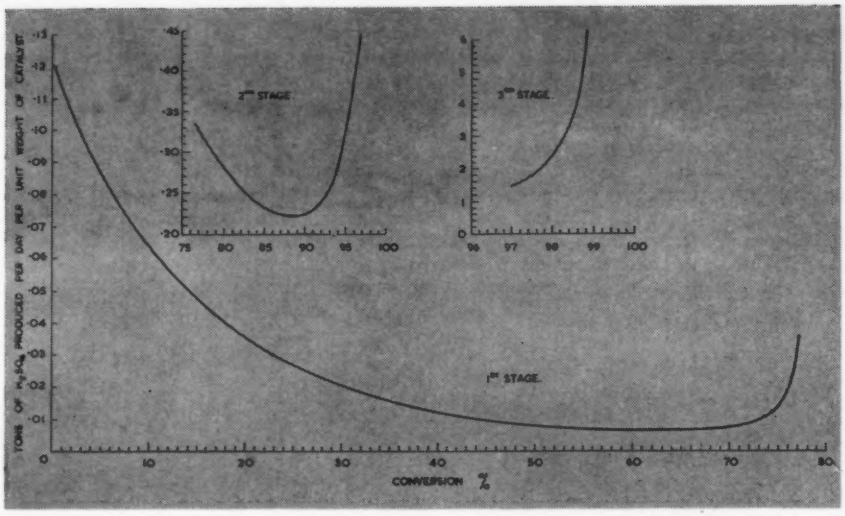

Fig. 8. Theoretical catalyst distribution ratio for equilibrium conditions in three-stage conversion of 8% sulphur gas.

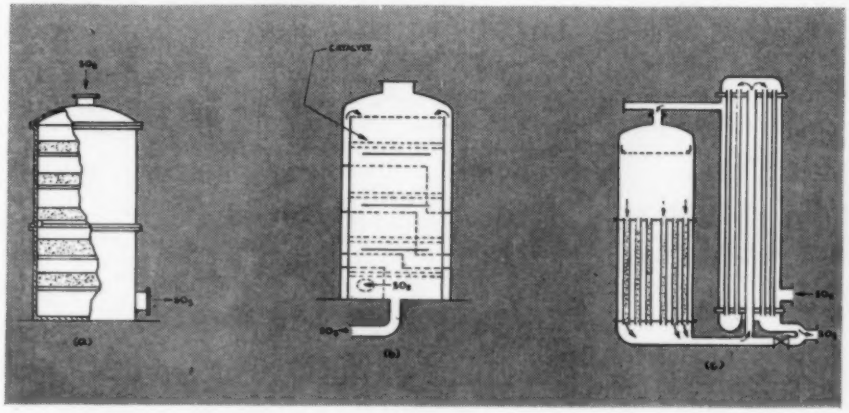

Fig. 9. (a) Old-pattern Grillo converter. (b) Regenerative Grillo converter. (c) Tentelew converter and heat exchanger.

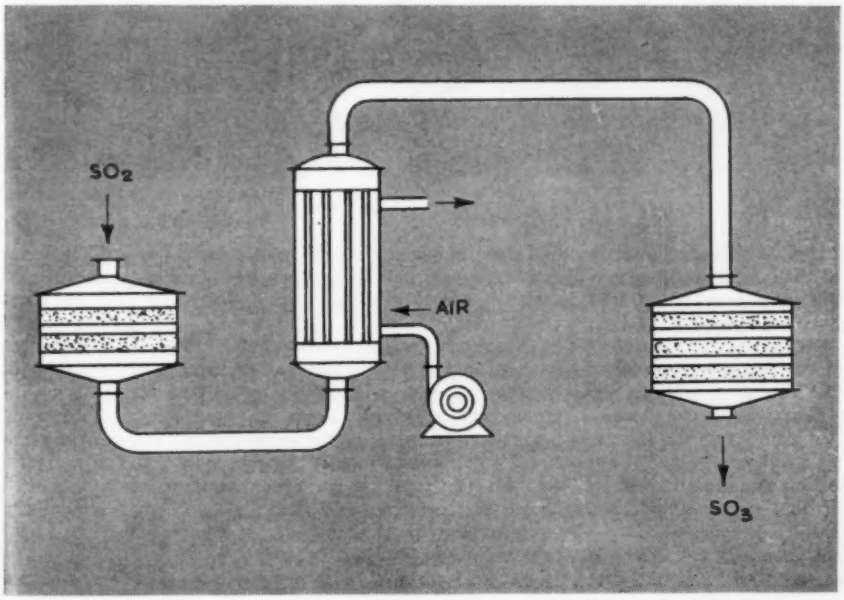

Fig. 10. Two-stage conversion with intermediate air-blown cooler.

which were first published in 1901. This converter was the first to operate on the internal heat-exchange principle. The catalyst which was used was platinised asbestos contained inside tubes supported on perforated plates. The cold gas entered at the bottom of the converter, passed upwards around the outside tubes and thence downwards through the converter to leave at the bottom. Originally this converter was designed to take the whole of the gas into the converter, but a later design incorporated a by-pass arrangement giving better temperature control.

Another type of internal heat-exchange converter was that developed by the Tentelew Company. This converter consisted of a vessel made up into two sections. The upper section contained a perforated plate in which was placed a number of cast-iron cones; on this perforated plate a layer of catalyst was placed of such a thickness that the cones projected into the open space above the tray. The cones transmitted heat from the catalyst into the space above it, giving some degree of heat to the incoming gas. The partially-converted gas passed into the lower section which contained further catalyst trays. No attempt was made to remove heat from these latter stages. This design of converter would not seem to have been successful, as the Tentelew Company later introduced a converter similar to the Badische type (see Fig. 9 (c)), except that above the tubes a relatively large void section was incorporated in which was installed a perforated distribution plate. The gases were slightly heated by contact with the converter walls.

With the early types of internal heat-exchange converter, all the incoming gas was exposed to the whole of the heat-exchange surface and with fluctuating gas concentrations accurate temperature control was not possible. Later designs incorporated methods of introducing cold gas at various places in the vessel.

In the early designs of converters for platinum, the loading was approximately 10 oz. a ton of acid a day. Improved designs resulted in a reduction to approximately 4 oz. a ton a day. One of the problems associated with the use of platinum was the danger of poisoning by small quantities of arsenical compounds, and it was necessary to have elaborate gas purification systems. Even if not poisoned, platinum suffers a gradual decline in activity, and it is stated that over a ten-year period the whole of the mass has to be replaced.

The early users of vanadium merely replaced the platinum and used the same contact vessels, but as vanadium was a much more durable material it was possible to improve on earlier designs, utilising either internal or external heat exchangers.

Those early designers favouring the internal heat exchanger endeavoured to remove the heat of reaction as formed. With external heat exchange advantage can be taken of the increased velocity of reaction at the higher temperatures, using a split contact system. This permits a conversion in the first stage of approximately 70% using only 30% of the total catalyst. The resulting gas which contains less SO_2 is then cooled in the interstage cooler and exposed to a relatively large amount of catalyst giving a relatively longer contact time.

A typical example of an early split contact unit is shown

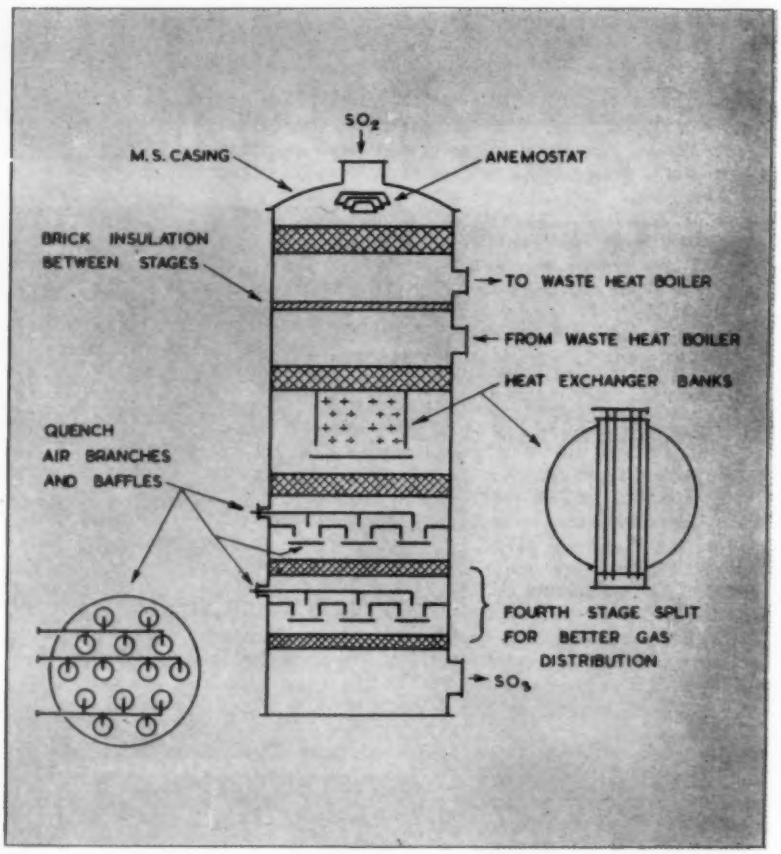

Fig. 11. Four-stage converter with two layers of catalyst in the fourth stage to improve gas distribution.

in Fig. 10. It consisted of two vessels of bolted construction fabricated in cast-iron, the first vessel containing approximately 30% of the total catalyst in two layers, gas distribution baffles being arranged between the catalyst layers. The second vessel contained the remaining 70% of catalyst in three layers with similar gas-distribution baffles. Between the two vessels was an interstage cooler consisting of a tubular heat exchanger using atmospheric air as the cooling medium when burning sulphur or cold gas when burning pyrites. A further development of the external heat-exchange converter was a single vessel of mild steel construction containing four layers of catalyst supported on cast-iron grids with cooling between each stage. In the case of sulphur burning, the excess heat is recovered in the form of steam. Throughout the development of converters, great attention has been paid to gas distribution, and recently converters have been designed with the fourth pass split into two layers of catalyst, with the object of improving gas distribution in the final stage (see Fig. 11).

Earlier in this article the subject of the advantages of cooling by quench air were discussed and a typical converter designed for quench air is shown in Fig. 11. The introduction of vanadium catalyst has also permitted considerable development of the internal heat-exchange converter. Using platinum catalyst, there was a high poisoning risk and the difficulties of replacing the mass made it a very costly operation. An internal heat-exchange converter has a fixed heat-exchange surface and for this reason is not so flexible as the external type, but it has the advantage of occupying much less floor space. The early designs using vanadium contained the whole of the catalyst inside the tubes, but this resulted in a high-pressure drop. Therefore, the catalyst layers were divided into the first mass outside the tubes supported on a perforated plate with the top sections of the tubes passing through the first mass. The cool gas entered the lower part of the vessel and circulated outside the tubes, passing upwards through the first catalyst layer and then down through the tubes containing the second pass.

The Lurgi internal heat-exchange converter tries to utilise the facts discussed above; namely, that maximum velocity of reaction is obtained at a temperature somewhat lower than that corresponding with the equilibrium temperature of the mixture. The gas mixture at 320–340°C is fed into the main body of the converter (see Fig. 12) and passes counter-current outside tubes containing catalyst. The gas then passes through a catalyst bed and down through the catalyst tubes. In this way maximum temperature is reached at the top of the converter at minimum conversion, and as conversion proceeds the gases are cooled by the surrounding incoming cold gases.

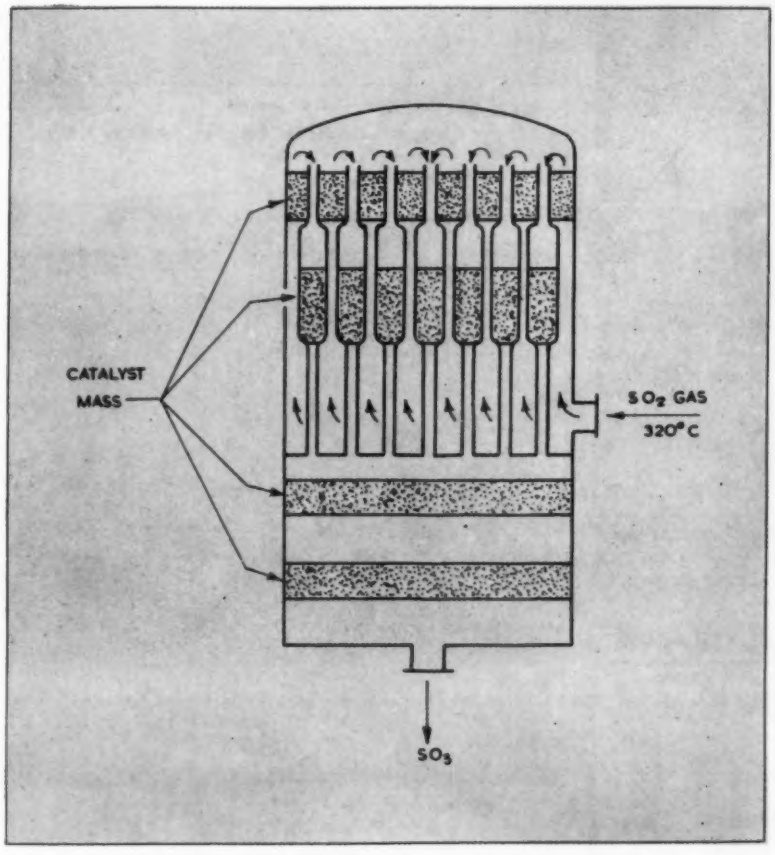

Fig. 12. The Lurgi internal heat exchange converter designed to operate at temperatures giving the maximum reaction velocity.

The authors wish to acknowledge the great help and inspiration from that most remarkable text-book, "Chemical Process Principles", by Hougan and Watson, and would also like to acknowledge the help of Mr. E. E. Bishop of Monsanto Chemical Co. for valuable discussion on catalysis, to members of the staff of Simon Carves for supplying drawings of converters and of many members of the staff at our Immingham factory. We are grateful to the Directors of Fisons Ltd. for permission to print this paper.

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THERMODYNAMIC PROPERTIES OF VINYL CHLORIDE

Temperature enthalpy and temperature entropy diagrams have been constructed based upon the theorem of corresponding states

by S. C. BANERJEE and L. K. DORAISWAMY

THERE are at present practically no published data on the P.V.T. relationship of vinyl chloride. This is true of many substances having molecular weights higher than the more simple compounds such as CO_2, CO, H_2O, NH_3, C_2H_4, etc. In the absence of these data, a precise calculation of thermodynamic properties is not possible. However, the thermodynamic properties of such substances may be estimated by the use of rigorous thermodynamic expressions generalised on the basis of the theorem of corresponding states. The object of this paper is to present the thermodynamic diagrams of vinyl chloride prepared by this procedure.

It is necessary to have the following data before a thermodynamic diagram, based on generalisations, can be constructed: vapour pressure, latent heat of vaporisation, and specific heat of vapour at constant pressure as functions of temperature; critical temperature and critical pressure; and liquid density at at least one temperature. Wherever experimental data are available they may be employed directly, but in the absence of such data use can be made of the many equations that have been proposed for estimating these properties. In Table 1 are listed some of the properties of vinyl chloride.

TABLE 1—PROPERTIES OF VINYL CHLORIDE

1. Molecular weight	62.5
2. Normal boiling point ...	−13.9°C ±0.1°C
3. Specific volume of saturated vapour at normal boiling point	332 cc./g.
4. Density of saturated vapour at normal boiling point ...	0.00301 g./cc.
5. Liquid density at normal boiling point	0.9692 g./cc.
6. Heat of vaporisation at normal boiling point ...	85.6 cal./g.
7. WATSON *ratio*, ρ/w, for liquid vinyl chloride ...	323
8. Critical temperature ...	158.4°C
9. Critical pressure	52.2 atm.
10. Critical ratio, $\frac{RT_c}{P_cV_c}$	3.80
11. Absolute entropy (at 298.1°K)	61.68 cal./°K/g. mole
12. Heat of formation at 298°K	9000 cal./g. mole

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Symbols

C_p = heat capacity at constant pressure, cal./g. mole/°K;
H = enthalpy, cal./g.;
P = pressure, atm.;
R = gas constant, litre-atm./g. mole/°K;
S = entropy, cal./g./°K;
T = temperature, °K;
t = temperature, °C;
V = volume, litres;
ρ = liquid density, g./cc.; and
w = liquid expansion factor.

Subscripts

c = critical state;
r = reduced state; and
sv = saturated vapour.

Superscript

* = ideal state.

Specific Heat Equation

RICHARDS[1] has computed the C_p values of vinyl chloride at various temperatures from spectroscopic data. These are plotted in Fig. 1. It is necessary in subsequent calculations to have a mathematical expression for C_p as a function of temperature. Consequently, the data of RICHARDS have been fitted, by using the method of least squares, into an equation of the form,

$$C^*_p = a + bT + cT^2 \qquad \ldots . (1)$$

where $a = 5.136$
$b = 2.985 \times 10^{-2}$
and $c = -1.020 \times 10^{-5}$.

The values of C^*_p calculated from Equation (1) are plotted on Fig. 1 to indicate the order of accuracy of the equation. The average deviation is about 1.5%.

VAPOUR PRESSURE

Experimental vapour pressure data for vinyl chloride are available[2] up to 60°C together with a correlation of the form,

$$\log p = a + b/T + c \log T + dT \qquad \ldots . (2)$$

where $a = 0.8420$
$b = -1150.9$
$c = 1.75$
$d = -0.002415$.

Based on this equation, vapour pressures have been calculated up to the critical point and the results plotted in Fig. 2.

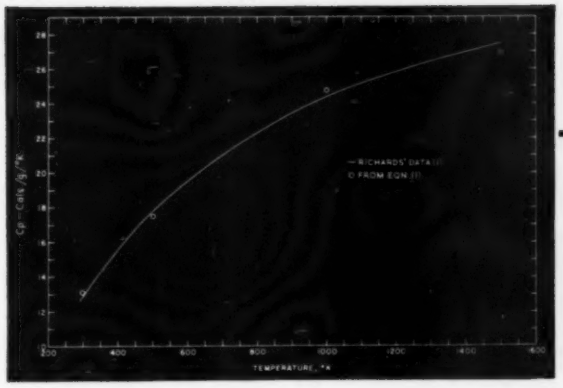

Fig. 1. Specific heat-temperature relationship of vinyl chloride.

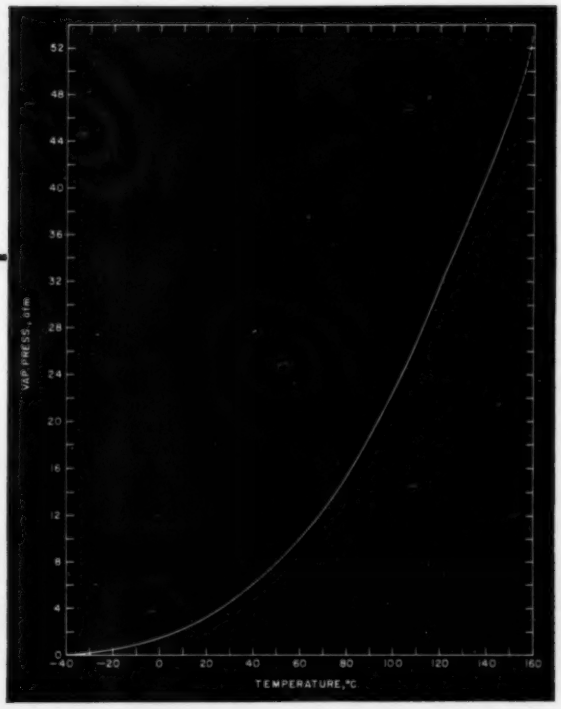

Fig. 2. Vapour pressure-temperature relationship of vinyl chloride.

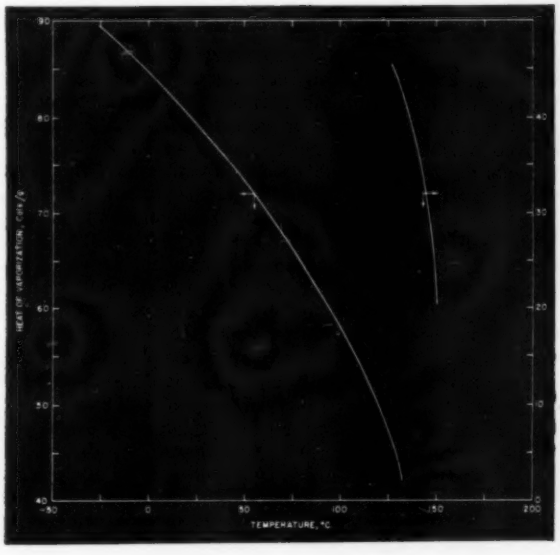

Fig. 3. Heat of vaporisation of vinyl chloride as a function of temperature (from Watson's correlation (3)).

LATENT HEAT OF VAPORISATION

Experimental data up to 50°C have been reported.[2] Heats of vaporisation at higher temperatures may be estimated from the generalised correlations of WATSON[3] and MEISSNER[4]; the former does not require a knowledge of vapour pressure-temperature relationship and has been found to be quite accurate. In Fig. 3 are plotted the heats of vaporisation at different temperatures calculated from the WATSON correlation. Values read from the MEISSNER plot agree closely with the curve of Fig. 3.

The heats of vaporisation calculated from the rigorous CLAPEYRON equation tend to be, on an average, about 3% lower than those of Fig. 3, but the use of this equation over the entire range is not possible as experimental liquid specific volume data are not available beyond 50°C. For consistency it is considered advisable to use Fig. 3 over the entire temperature range up to the critical point.

Construction of Temperature Enthalpy and Entropy Diagrams

DATUM

Enthalpy is a property which can only be defined relative to a given datum plane. In the case of entropy, although absolute values may be available or can be estimated, it is also frequently expressed relative to a datum value. The datum selected here is saturated liquid vinyl chloride at its normal boiling point (−14°C); at this temperature both enthalpy and entropy are arbitrarily assigned zero values.

TEMPERATURE-ENTHALPY CHART

The procedure for constructing this chart is briefly described herewith. The basic curve for these calculations, as pointed out by HOUGEN and WATSON,[5] is the enthalpy of ideal vapour (at zero pressure), H^*, as a function of

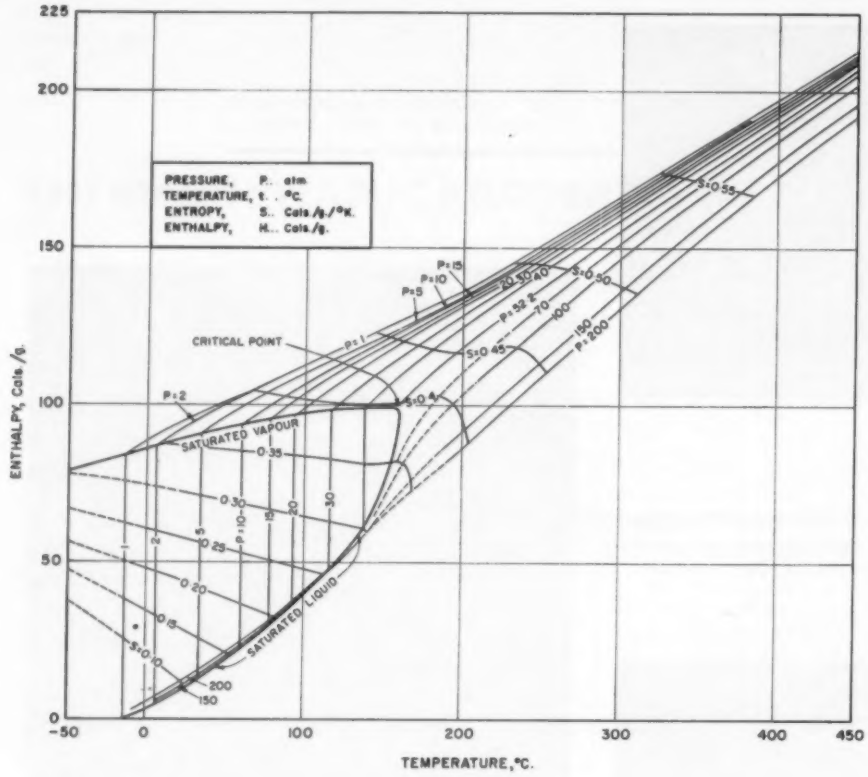

Fig. 4. Enthalpy-temperature chart for vinyl chloride.

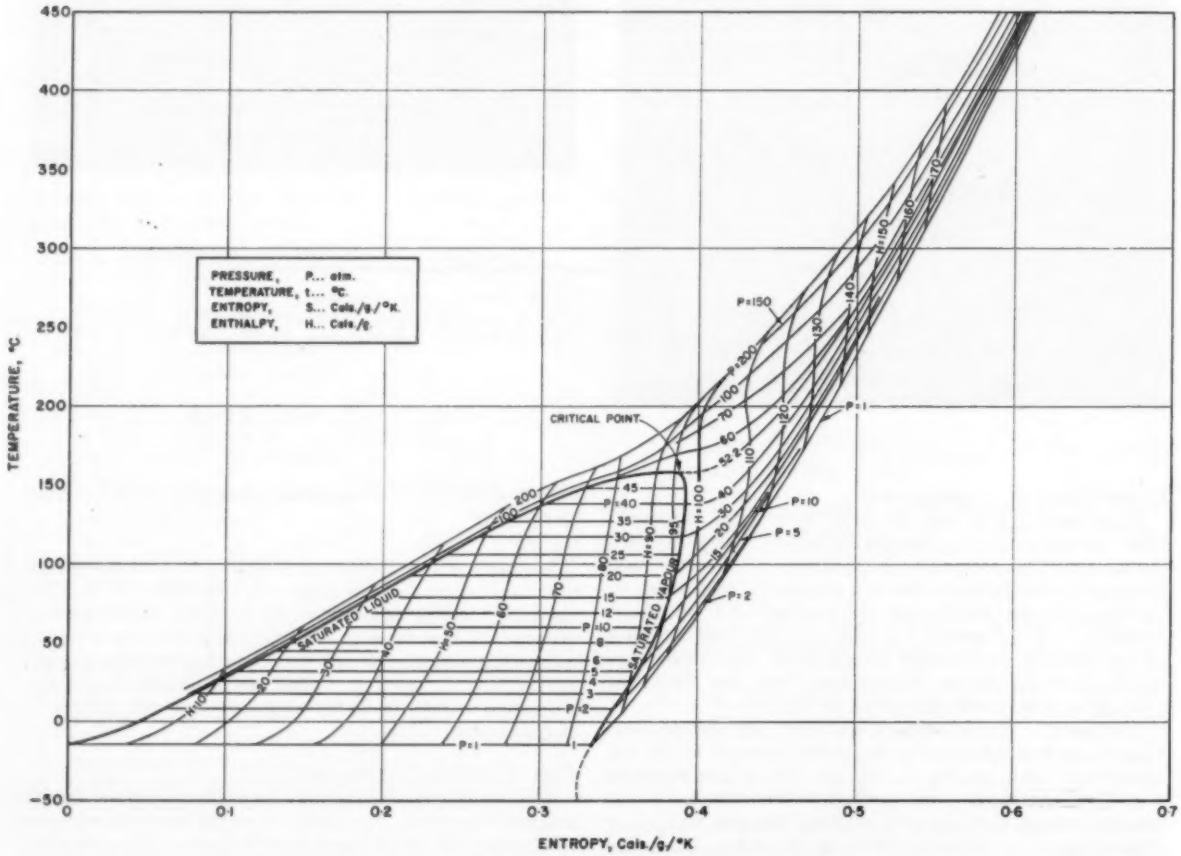

Fig. 5. Entropy-temperature chart for vinyl chloride.

temperature. This is established by using the equation:

$$H^* - H^*_{259.2} = \int_{259.2}^{T} C^*_P \, d\,T \qquad \ldots.(3)$$

The value of $H^*_{259.2}$ is calculated from a knowledge of heat of vaporisation at 259.2°K and the enthalpy correction corresponding to 259.2°K and 1 atmosphere. The correction term is determined by using the chart developed by WATSON and NELSON[5, 6] for estimating it as a function of T_r and P_r. Thus the value of $H^*_{259.2}$ comes to 87.46 cal./g.

Substituting Equation (1) for C^*_p and integrating,

$$H^* = 87.46 + \frac{1}{62.5}\left[a\,(T - 259.2) + \frac{b}{2}\,(T^2 - 6.72 \times 10^4) + \frac{c}{3}\,(T^3 - 1.73 \times 10^7)\right] \qquad \ldots.(4)$$

H^* can now be computed at various values of T from Equation (4).

To determine the enthalpy of saturated vapour (H_{sv}) at any temperature, it is necessary to evaluate the pressure correction for enthalpy ($H^* - H_{sv}$) to account for non-ideality due to the vapour pressure at that temperature. This, again, may be done by using the WATSON correction charts. Knowing H^* and the correction factor, H_{sv} can be evaluated. The enthalpy of saturated liquid is then determined from a knowledge of H_{sv} and the heat of vaporisation obtained from Fig. 3.

Constant pressure lines are established in a manner analogous to that employed for the saturation curves. In the compressed liquid region, however, the correlation employed for determining the pressure correction for enthalpy in the vapour region is no longer valid. It is necessary to employ the liquid enthalpy correction chart developed by WATSON. Since the correction factor in this case is expressed as $[(H_c - H)\,\rho/wP_c]$, use of this correlation requires a knowledge of the ratio, ρ/wP_c, its value being constant for a given liquid. For vinyl chloride, ρ at −13°C is 0.969 g./cc. The value of the expansion factor, w, at −13°C, as determined from the generalised chart constructed for estimating it as a function of T_r and P_r,[3] is 0.124. Thus, using consistent units,

$$\rho/wP_c = 6.2.$$

The constancy of this ratio for vinyl chloride has been verified by evaluating it at other temperatures. From a knowledge of this, the pressure correction for the enthalpy of liquid vinyl chloride can be determined by the WATSON correlation.[3]

TEMPERATURE-ENTROPY CHART

The procedure is similar to that employed in the construction of the T-H chart. Equation (3) is replaced by Equation (5):

$$S^* - S^*_{259.2} = \int_{259.2}^{T} \frac{C^*_P}{T}\, d\,T \qquad \ldots.(5)$$

which, on substitution of Equation (1) for C^*_p and integration, gives:

$$S^* = 0.343 + \frac{1}{62.5}\left[a\,ln\,\frac{T}{259.2} + b\,(T - 259.2) + \frac{c}{2}\,(T^2 - 6.72 \times 10^4)\right] \qquad \ldots.(6)$$

Pressure correction charts for entropy, both for the gaseous and liquid states, are presented by HOUGEN and WATSON.[8]

Having established the two diagrams as outlined above, constant enthalpy and constant entropy lines are established by cross-plotting the data. The complete T-H and T-S diagrams are shown in Figs. 4 and 5 respectively.

PROBABLE ERRORS

Diagrams prepared from generalisations are necessarily less accurate than those based on experimental data. However, for most engineering purposes, the accuracy of these diagrams is satisfactory, the magnitude of errors being approximately equal to that of the generalised charts on which these are based.

The correction charts employed in these calculations are all based on the generalised compressibility factor chart. Although the many compressibility charts that have appeared in the literature have been prepared from experimental data, nevertheless the constancy of the critical ratio, RT_c/P_cV_c, may be considered to be implicit in the construction of these charts.* The best average value of this ratio is 3.65 to 3.7. For substances having a critical ratio equal to this value, the errors involved in the use of the generalised charts may be expected to be the lowest. For vinyl chloride, the estimated value of this ratio is 3.80[7] which is only about 3% higher than the average value used. It is reasonable, therefore, to expect errors not exceeding 5% in using these diagrams. If the critical ratio were far different from 3.65 to 3.70, it would be necessary to base all the calculations on the apropriate generalised chart of LYDERSON, GREENKORN and HOUGEN,[8] who have presented these charts for various values of the critical ratio.

INTERNAL CONSISTENCY OF DIAGRAMS

The internal consistency of the two diagrams can be tested by means of the following equation:

$$dH = TdS + VdP \qquad \ldots.(7)$$

For a given pressure, in the two-phase region, both T and P are constant, so that integration of Equation (7) gives,

$$H_2 - H_1 = T\triangle S \qquad \ldots.(8)$$

The values of $T\triangle S$ determined from Fig. 5 may be compared with those of $(H_2 - H_1)$ obtained directly from Fig. 4. A number of checks show that agreement in this region is almost quantitative.

For a given pressure, in the one-phase region, Equation (7) may be integrated to give:

$$H_2 - H_1 = \int_{S_1}^{S_2} T\, d\,S \qquad \ldots.(9)$$

The right-hand side of Equation (9) may be evaluated by graphical integration of the appropriate constant pressure line of the T-S diagram between the limits, S_2 and S_1 corresponding to temperatures T_2 and T_1 respectively. The value so determined may be compared with that of $(H_2 - H_1)$ obtained from the T-H diagram. The results are found to agree with an average deviation of ±3%. In the vicinity of the critical point, however, errors of a larger magnitude (±8%) are encountered. The experimental data available being fragmentary, absolute checks are not possible.

* SU (*Ind. Eng. Chem.*, 1946, **38**, 803) suggests that the constancy of the critical ratio is not essential.

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SAFETY FACTORS AND THE TENSILE TEST

THE principal property of material construction which the designer uses to fix the safe working stress of a vessel is the ultimate tensile stress; the ratio of this stress to the design stress is known as the factor of safety. According to the design code used, this may have a range of values which, according to DOREY (quoted by LANE[1]), may vary from 4 to 5.4, while according to WEIL[2] it may vary from 3 to 4.

The assumption underlying the factor is that a margin of safety will be available to meet loads of unexpected intensity, or stresses, whose magnitudes cannot be ascertained by any known means. For this reason the term factor of safety is often looked upon as a factor of ignorance. Objections can be raised against the assumption of design stresses based upon the ultimate tensile strength (U.T.S.). For one thing the type of failure which occurs in practice seldom resembles the ductile type of fracture which a specimen suffers under the tensile test. Again, the stress at which the material of a vessel will fail in practice and the U.T.S. need not be identical. WEIL[2] has pointed out that the tensile failure of material takes place when its strain-hardening ability is no longer able to compensate for the reduction in area that occurs under plastic flow. If the load at this point is maintained, a sudden breakage occurs, but this does not happen to the tensile test specimen because its straining ability outruns the speed of movement of the testing machine's cross head; therefore, the load, instead of being maintained, drops off. This is shown by the reduction in load beyond the U.T.S. and breakage of the specimen at a point beyond the maximum.

In view of such objections, WEIL has made a new approach to design stresses and safety factors. He regards tensile rupture as an instability phenomenon and he introduces the concepts of "logarithmic strain" and "true stress", based upon the changing cross-sectional area of the material. In this treatment plastic strains are considered to predominate and elastic strains are ignored; the values of the effective stresses and strains characterising the instability of thin-walled tubes cannot reach the same values for the instability of the tube material in pure tension.

The effective stress may be defined by

$$\frac{\sigma_{eff}}{B} = \left(\frac{n}{\sqrt{3}}\right)^n \qquad \ldots.(1)$$

where n = the strain hardening exponent
B = the hardness factor, psi
and the effective strain $\epsilon_{eff} = \sqrt{3}n$ .... (2)

In Fig. 1 the effective instability stresses for a thin-walled tube, determined by means of this equation, are shown for various values of n. The corresponding rupture stresses in the tensile test specimen are shown in the doted line of

Table 1—True Stress-Strain Properties of Some Metals[2]

Type of Metal	Aluminium Alloys: 4·5 Cu. 1·5 Mg.	Aluminium Alloys: 1·6 Cu. 2·5 Mg. 5·6 Zn.	Low Carbon Steel, Annealed	Stainless Steel, Annealed
Hardness Factor, B, in 1000 p.s.i.	100·0	54·5	100·0	190·0
Strain-hardening Exponent, n	0·168	0·145	0·301	0·415

Symbols Used

B = hardness factor, psi;
E = welded joint efficiency, longitudinal seam;
Q = safety factor quotient;
$S.F.$ = safety factor;
c = corrosion allowance, in;
e = conventional strain (with subscripts);
e = base of nat. logarithms (without subscripts);
n = strain hardening exponent;
σ_c = true circumferential stress, psi;
σ_{burst} = true bursting stress, psi;
σ_{eff} = true effective tensile stress;
p = pressure in vessel, psi;
r_o = internal radius of vessel, in.;
s_{ult} = ultimate tensile stress, U.T.S. psi;
s_{des} = conventional design stress, psi;
s_{burst} = conventional circumferential stress at maximum pressure in vessel, psi;
s_c = conventional circumferential stress, psi;
t_o = thickness of vessel, in.;
ϵ_{eff} = effective logarithmic strain; and
ϵ = logarithmic strain.

Fig. 1. These effective stresses have to be converted to engineering design stresses. This is carried out in two steps. The true logarithmic circumferential strain is given by

$$\epsilon_c = n/2 \qquad \ldots.(3)$$

and ratio of true bursting stress to hardness factor

$$\frac{\sigma_{burst}}{B} = \frac{2}{\sqrt{3}}\left(\frac{n}{\sqrt{3}}\right)^n \qquad \ldots.(4)$$

For a thin-walled vessel the true stress is converted to the design stress by:

$$s_c = \sigma_c\, e^{-2\epsilon} = \sigma_c\, e^{-n} \qquad \ldots.(5)$$

and by substitution of (5) into (4):

$$\frac{s_{burst}}{B} = \frac{2}{\sqrt{3}} \cdot \left(\frac{n}{\sqrt{3}}\right)^n e^{-n} \qquad \ldots.(6)$$

This expression is represented graphically in Fig. 2. The dotted line gives values for the tensile test specimen obtained from:

$$\frac{s_{ult}}{B} = n^n\, e^{-n} \qquad \ldots.(7)$$

Fig. 2 shows that at low values of n the true stress at bursting is greater than the tensile stress at necking; when the value of n is high, i.e., material with a high strain hardening ability, the opposite is the case. From (6) and (7)

$$\frac{s_{ult}}{s_{burst}} = \frac{\sqrt{3}^{n+1}}{2} \qquad \ldots.(8)$$

which may be expanded with omission of terms of higher order to

$$\frac{s_{ult}}{s_{burst}} = \frac{\sqrt{3}}{2}\left(1 + \frac{n}{2}\ln 3\right) \qquad \ldots.(9)$$

From the thin-walled cylinder formula:

$$\sigma_c = \frac{p\, r_o}{t_o}$$

and substitution σ_c *for* s_{burst} in (9) gives

$$s_{ult} = \frac{\sqrt{3}}{2}\, p\, \frac{r_o}{t_o}(1 + 0.549n) \qquad \ldots.(10)$$

This expression may be compared with those offered by the various design codes for determining the working pressure or the plate thickness.

For safety factors of vessels designed on circumferential stress alone, a safety factor quotient (Q) between ves-

sel and tensile members is used. This is defined by:

$$Q = \frac{S_{burst}}{S_{ult}} \qquad \ldots.(11)$$

which from (6) gives

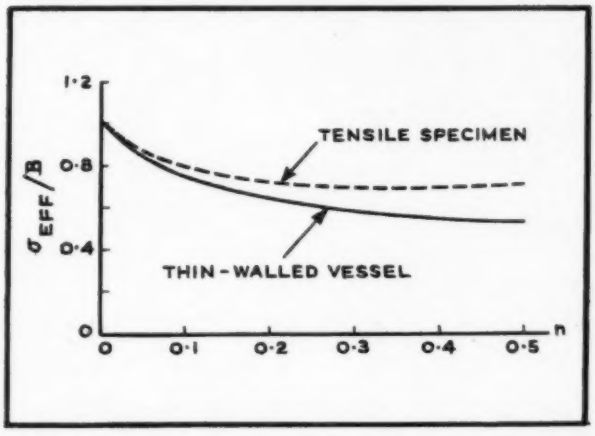

Fig. 1. Effective instability stresses in thin-walled vessel and tensile specimen compared.

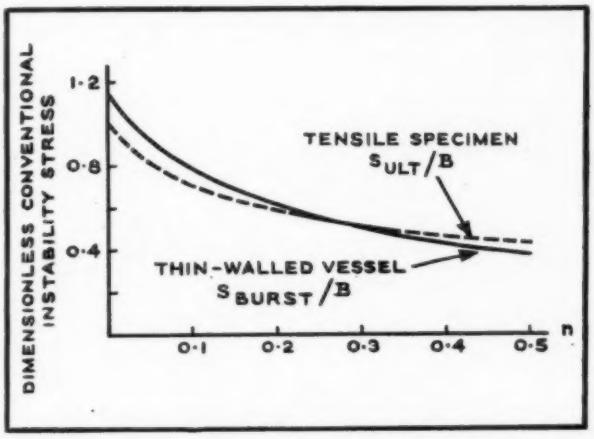

Fig. 2. Conventional instability stresses derived from Equations (6) and (7).

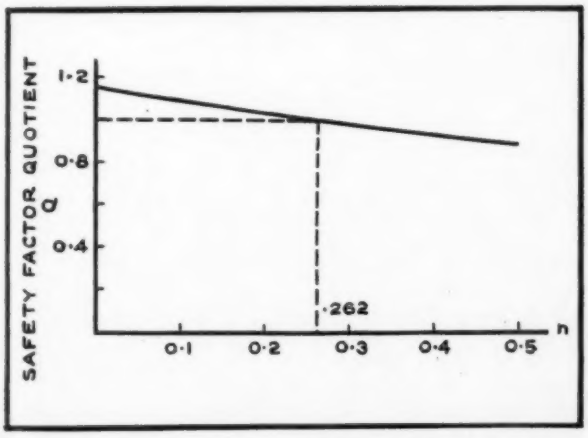

Fig. 3. Values of the safety factor quotient for different vessels of the strain hardening experiment.

$$Q = 1.55\ (0.577)^n \simeq 1.155 - 0.634n \qquad \ldots.(12)$$

This function is plotted in Fig. 3 for different values of n. Equation (12) indicates that where materials are subjected to uniaxial tension only, the design safety factor based upon the tensile test represents a true safety factor.

Equation (11) may be written:

$$\frac{S_{burst}}{S_{des}} = Q.\frac{S_{ult}}{S_{des}} \qquad \ldots.(13)$$

If the same design stresses are adopted for vessel and tensile member then

$$(S.F.)_{vessel} = Q(S.F.) \qquad \ldots.(14)$$

Thus the safety factor for bursting of thin-walled vessels depends upon Q. Fig. 3 shows that the safety factor is greater than the tensile safety factor when n is less than 0.262. When n is greater than this, the available safety margin is less than that inferred from tensile tests.

The magnitude of the strain-hardening exponent n is important. Ideally plastic materials ($n = o$) are not encountered in practice and most ductile materials in the annealed state have values of n which lie between 0.2 and 0.45. Cold-rolled materials, on the other hand, have much lower values which vary from 0.05-0.25. Unfortunately, "n" values are known only for a few metals and alloys.

EXAMPLE—COMPARISON OF SAFETY FACTORS AND WALL THICKNESSES FOR A STAINLESS-STEEL VESSEL

The following data are given;

Operating temperature	= 150°C
Normal working pressure	= 200 psi
U.T.S.	= 35 tsi
Allowable stress according to B.S.C. 1500[3]	= 19600 psi
Vessel i.d.	= 48 in.
Hardness factor B	= 190,000 psi
Strain hardening exponent n	= 0.145

According to the above code, the safety factor based upon the U.T.S. is 4. According to Equation (12) (or Fig. 3),

$$Q = 1.155 - 0.634 \times 0.415 = 0.892$$

and from (14)

$$S.F._{vessel} = Q.(S.F.)_{tension} = 0.892 \times 4 = 3.57$$

Wall thickness according to the code equation[3] is given by

$$t = \frac{2rp}{2ES_{design} - p} + c$$

If E = 0.90 and no corrosion allowance is made,

$$t = \frac{200\ .\ 48}{2\ .\ 19600\ .\ 0.90 - 200} = 0.273 \text{ in.}$$

If the expression by WEIL in this summary is used

$$t = \frac{\sqrt{3}}{2}\, p\, \frac{r_o}{S_{ult}}\,(1 + 0.549n)$$

$$= \frac{\sqrt{3}}{2}\ .\ 200\ .\ \frac{24}{19600}\,(1 + .228) = 0.261$$

With a joint efficiency $E = 0.90$, this becomes $t = 0.288$ in. The tensile necking strain from $e_x = e^n - 1 = 0.514$, while the bursting strain $e_c = e^{2/n} - 1 = 0.245$.

The necking strain in tension is thus much greater than the circumferential bursting strain.

This example illustrates the point made earlier (Fig. 3). that for annealed materials the U.T.S. based safety factor for bursting does not provide such a margin of safety that its magnitude implies.

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BARRIERS TO THE TRAINING OF GRADUATE SCIENTISTS AND ENGINEERS

A study of the financial problems involved in pursuing further education in Great Britain

by W. E. EGNER, M.A.(Cantab.), B.Sc.(Dunelm), F.S.S.

ACCORDING to the 1951 Census,[1] about 15% of the young people in England and Wales between the ages of 15 and 19 years were in full-time attendance at educational establishments and a further 4% in part-time attendance. In the year 1956 only 9% of each age-group was staying at school until the pre-university year (say 17+).[2] Such is the scale of further education in England and Wales.

To approximate to the situation in the U.S.A. or the U.S.S.R., the above percentages would have to be increased several times over. The estimate of the Advisory Council on Scientific Policy in 1956 was that by 1970 our annual output of qualified scientists and engineers should be approximately doubled.[3] The path to such changes lies mainly through the sixth forms and universities. While in some cases part-time study is possible, this is successfully achieved to the standards considered here by only a small minority of young people. It is likely that full-time courses at universities or full-time or sandwich courses at Colleges of Advanced Technology will be necessary in future rather than part-time study.

Diplomas of Technology appear to be almost entirely "works-based", the students receiving their salaries and fees from their firms while engaged on periods of full-time study. But the road to the university, in at least 70% of cases,[3] is supported by scholarships and grants of various kinds. Some of these enable a student to be entirely self-supporting: most of them, however, require supplementation by parents. Moreover, even before the student enters the university at 18 his upkeep is a considerable financial burden to his parents. At 16 or 18 the able boy has roughly two courses of action between which to choose. If he leaves school and enters employment he will receive wages or salary: if he remains at school and/or proceeds to university he may or may not receive financial relief. It is here that comparisons are made, and while further full-time education may bring higher remuneration in due course, this is by no means certain. In any case, financial difficulties cannot usually be postponed to an uncertain future.

The purpose of this article is to examine these financial problems, which cause anxious concern to countless young people and their parents. Sometimes the period most feared is that from 16+ to 18+, while the boy is in the sixth form: sometimes it is the period 18+ to 21+, at university. But in one way or another large numbers of able young people are deflected from further education, as has been recognised in fairly recent authoritative statements.[4] Moreover, there is no alternative to the sixth form and university road for would-be teachers of science or mathematics and other specialists nor for university lecturers and professors; on the supply of such key people the whole of the educational structure, and indeed the national structure, rests.

In order to obtain a clear picture of the situation we first examine the salaries available to able school leavers from 16+. Then an attempt is made to assess financial relief available for those who remain at school, and proceed on to university as undergraduates, and remain as postgraduate students.

Salaries Available to School Leavers[5]

Taking as our academic standard four or more subjects at 'O' G.C.E. level, inquiries show that the following figures for boys of 16+ are reasonably common.

Industry

Age	*Salary*
16+	£200
17+	£230
18+	£290

Graduate Apprentices—about £600.

Commerce

	Civil Service			
Age	*Clerical*	*Executive*	*Banking*	*Insurance*
16+	£250	—	—	—
17+	£280	—	£275	£265
18+	£315	£365	—	—

The Professions. In the professions such as accountancy, law and architecture there is considerable variation: a few firms require a premium to be paid and this is often returned as salary. More generally, firms offer annual sums ranging from £50 upwards, to at least £220 at 16+, rising to £430 at 23 years of age.

Financial Benefits to Parents

YOUNG PEOPLE AT SCHOOL

From 15+ the possible sources of financial benefits are threefold—namely, income tax allowance, family allowance and maintenance allowance.[6] Each of these three varies according to parental income and family circumstances, and examples are given in Table 1. All figures are in pounds per annum.

Mr. W. E. Egner *is Headmaster of South Shields Grammar-Technical School for Boys, and is a pioneer of "operational research" in schools. During the war he served for a time as Scientific Adviser to an R.A.F. Command. Mr. Egner was a Fellow of his College in Durham University, and is a B Star Wrangler of Cambridge.*

TABLE 1—FINANCIAL BENEFITS TO PARENTS IN RESPECT OF A CHILD OF 16 OR 17 REMAINING AT SCHOOL

Family	*Gross Income*	*Maintenance Allowance*		*Combined difference in net income due to family allowance and income tax relief (Child Allowance)*	*Total*	
		16 years old	*17 years old*		*16 years old*	*17 years old*
(a) Mother, father, one child of 16 or 17	300	55	65	0	55	65
	400	30	40	7	37	47
	800	0	0	52	52	52
	1000 to 2000 inclusive	0	0	64	64	64
(b) Mother, father, one child under 11, one child of 16 or 17	300	55	65	21	76	86
	400	42.5	53.5	21	63.5	74.5
	800	0	0	59	59	59
	1000	0	0	72	72	72
	1200 to 2000 inclusive	0	0	77	77	77
(c) Mother, father, one child under 11, one child in age range 11 to 16, one child of 16 or 17	300	55	65	26	81	91
	400	55	65	26	81	91
	800	0	0	53	53	53
	1000	0	0	68	68	68
	1200	0	0	80	80	80
	1400 to 2000 inclusive	0	0	81	81	81

TABLE 2 — FINANCIAL CONTRIBUTION TO BE MADE BY PARENTS OF STUDENT HOLDING STATE SCHOLARSHIP

Family	Gross Income	Income Tax Relief *gained* (a)	Contribution *Made* under State Scholarship Scheme (b)	Total Contribution *Made* (b) — (a)
	£	£	£	£
(a) Mother, father, one child (18+) at university	300	0	0	0
	400	7	0	−7
	800	51	40	−11
	1000	64	67	3
	1200	64	94	30
	1400	64	120	56
	1600	64	150	86
	1800	64	176	112
	2000	64	202	138
(b) Mother, father, one child under 11, one child (18+) at university	300	0	0	0
	400	0	0	0
	800	44	18	−26
	1000	58	44	−14
	1200	64	74	10
	1400	64	97	33
	1600	64	127	63
	1800	64	154	90
	2000	64	180	116
(c) Mother, father, one child under 11, one child between 11 and 16, one child (18+) at university*	300	0	0	0
	400	0	0	0
	800	32	0	−32
	1000	49	22	−27
	1200	62	48	−14
	1400	64	74	10
	1600	64	104	40
	1800	64	130	66
	2000	64	157	93

Note: The Ministry of Education is prepared to approve payment by local education authorities of the scale of maintenance allowances set out in this table, but the Ministry cannot say if all authorities make such payments, or if any payments which they may make are in accordance with this scale.

** In this case the parents will be eligible to receive family allowance.*

UNDERGRADUATES

The State Scholarship Scheme is taken as the basis for calculations[7] of the financial benefits to parents of undergraduates. This assumes standard expenditure for tuition, maintenance, vacation courses and so on which varies according to the university and takes into account whether the student lives in a hostel, in lodgings or at home. The parental contributions depend upon a means test. From the gross income are deducted sums of £150 for each dependent child, superannuation and similar contributions up to 10% and allowances for such items as mortgage interest. The figure produced is known as the "net income". If this is £450 or less there is no parental contribution. But the contribution becomes payable at the rate of £30 for each additional £200 of net income up to a net income of £1800. It increases up to a rate of £30 for each additional £100 of net income of £2300 or above. At £2300 the parental contribution is £307 per annum. To offset parental contributions, there is the net income tax relief due to a child allowance of £150 which continues while a student is at the university.

In Table 2 are set out the net amount of contributions to be made by the parents. This takes into account contributions under the State Scholarship Scheme and income tax relief, assuming an allowance of 10% for superannuation and similar reliefs.

The Postgraduate Student

Awards for postgraduate study at universities are many and varied, but in the main they are now granted by the Ministry of Education to selected arts students, and by the Department of Scientific and Industrial Research in the cases of science (including mathematics) and technology. The monetary value of both types of award is a little greater than for State Scholarships,[8] but no account is taken of parental income. Thus, in addition to tuition fees, their value ranges from about £245 a year for students living at home and attending any university outside London to £380 for students at Oxford and Cambridge living in college, hostel or lodgings.

Conclusions

From the figures given the following conclusions can be drawn:

(i) Even at their maximum, allowances available are considerably below comparable salaries.

(ii) Children remaining at school from 16 to 18 represent in effect, a financial sacrifice of the order of £200 per year to their parents.

(iii) Undergraduates at university receiving maximum maintenance allowances fare worse than young men in employment. Among the higher income groups the financial burden on their parents is very considerable.

(iv) Graduates undertaking postgraduate work generally do so at a fairly large financial loss.

These financial losses must act as barriers to higher education.

Thus, if university education is not to be regarded as a luxury, if we wish to avoid a great financial distinction between students at universities and works-based students at Colleges of Advanced Technology, and if the nation is to get the scientists and engineers which it so urgently needs, it is clear that immediate increases must be made in maintenance allowances. This is true for university students, and for able boys and girls at school in sixth forms. Moreover, means tests should be adjusted so that further education does not equate itself with undue financial sacrifice for boys and girls from any home.

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[1] "Census 1951 Great Britain—1% Tables, Part II", H.M.S.O., 1952, Table VIII, 1.
[2] "Scientific and Engineering Manpower in Great Britain", H.M.S.O., 1956, paragraph 52.
[3] "Education in 1956". Cmd. 223, H.M.S.O., Ch. VI, paragraphs 1 and 2.
[4] "Early Leaving", 1954, H.M.S.O., paragraphs 23-27.
[5] Various Ministry of Labour publications and other documents.
[6] Circular 327 (July 12, 1957), Ministry of Education.
[7] Administrative Memo. No. 502 (April 27, 1955), Ministry of Education.
[8] 1956/7 Grants Year Book—National Union of Students, pp. 96 and 97, and "Notes on D.S.I.R. Grants", 1958, H.M.S.O., p. 6.

New Pharmaceutical Plant

Cyanamid Expand at Gosport

A worker in the Aureomycin plant where crude Aureomycin is refined for use in the pharmaceutical section. Solvents used in this process are piped to the plant from a tank farm.

A FEATURE of the new £700,000 pharmaceutical factory of Cyanamid of Great Britain Ltd., at Gosport, recently opened by Sir Alexander Todd, Professor of Organic Chemistry, Cambridge University, is the mounting of air-conditioning and other services above the plant in a false roof so that the working areas, which include sterile rooms, do not have to be disturbed for maintenance. Each light fitting, for example, may be removed from above as a unit by uncoupling a plug.

The chemical processes undertaken at the plant include the synthesis of Artane (an anti-spasmodic drug), and Diamox (an oral diuretic), the recrystallisation of crude Aureomycin antibiotic and the conversion of part of the product to Achromycin by des-chlorination and hydrogenation. Most of the processing is conducted in glass or glass-lined reactors of up to 1000 litres capacity. The new installation incorporates also a tank farm for solvents and a pharmaceutical section for the preparation of ointments, tablets, etc. Much of the output of the factory is destined for export.

The plant is the first to be built in Great Britain by the Cyanamid organisation, and it will be staffed by British staff numbering nearly 300 and will be worked by the company's Lederle Laboratories division. This latter division is one of five operating divisions within the company, the others being farm and home, surgical products, mining chemicals and general chemicals.

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SCALE-UP RELATIONSHIPS FOR HEAT TRANSFER IN VOTATORS

Relationships useful to designers dealing with various aspects of heat transfer in these widely-used machines are presented

by A. H. P. SKELLAND, Ph.D., B.Sc., A.R.I.C., A.M.I.Chem.E., A.F.Inst.Pet.

THE Votator, a double-pipe, scraped-surface heat exchanger, is extensively used in the food and chemical industries; for example, in the crystallising of petroleum waxes, the plasticising of margarine and shortenings and in sulphation and sulphonation reactions. Despite its widespread applications, no published attempt had been made until recently[1] to correlate scraped-film heat transfer in this equipment with physical properties, operating conditions and plant dimensions.

Reference 1 correlates the scraped-film coefficient of heat transfer, h_s, as:

$$h_s = 4.9 \frac{k}{D_t} \left(\frac{D_t v \rho}{\mu}\right)^{0.57} \left(\frac{C_p \mu}{k}\right)^{0.47} \left(\frac{D_t N}{v}\right)^{0.17} \left(\frac{Dt}{L}\right)^{0.37} \quad \ldots (1)$$

With the advent of this recent correlation, it has become possible to derive scale-up relationships for duplication of various patterns of heat transfer in two Votators of differing dimensions. These relationships are subject only to the same accuracy limitations as applied to the original correlation[1] and are valid for the particular flow régimes for which exponents on the relevant groups in the correlation were evaluated.

These flow régimes are described elsewhere,[1] and are shown to be characterised by values of $D^2_m N\rho/\mu$ *at least* between 40 and 2030, with values of $(D_t - D_s)\ v\rho/\mu$ *at least* between 0.7 and 135, probably extending beyond these limits. This covers a wide field of conventional Votator application. The correlation was derived for Votators in which the ratio of shaft to tube diameter (D_s/D_t) is between 0.75 and 0.81 and where the design of shaft plus scraper blades is similar to that shown in Reference 1. In a large proportion of Votators the values of D_s/D_t are within this range—effects of further variation in this group have not yet been established. These restrictions consequently apply to the scale-up relationships developed here.

TABLE I—ASPECTS OF HEAT TRANSFER WHICH MAY BE MADE THE SAME IN TWO VOTATORS

1	Rate of heat transfer per sq. ft of Votator-tube surface.
2	Total heat transfer per lb. of material.
3	Rate of heat transfer per lb. of material.
4	A combination of 1 and 2 above.
5	A combination of 1 and 3 above.
6	A combination of 2 and 3 above.
7	A combination of 1, 2 and 3 above.

Symbols

C_p = specific heat, Btu/lb. °F;
D_m = twice distance from scraper-blade edge to shaft axis (D_m effectively equals D_t), ft;
D_s = diameter of shaft carrying scraper blades, ft
D_t = internal diameter of Votator tube, ft;
h_s = scraped film coefficient of heat transfer, Btu/ft² hr °F;
k = thermal conductivity, Btu/ft² hr °F/ft;
L = scraped tube length, ft;
N = rotational speed of shaft with blades, rev/hr;
Q = total heat transferred/unit time, Btu/hr;
U = overall coefficient of heat transfer, Btu/ft² hr °F
v = average linear flow velocity of fluid through Votator, ft/hr;
W = mass flow rate through Votator, lb./hr;
Δt = log mean temperature difference across the scraped film = *overall* $\Delta t \times U/h_s$, °F;
ρ = fluid density, lb./ft³;
μ = absolute fluid viscosity, lb./ft hr; and
φ = Constant
Suffixes 1 and 2 = first and second Votators.

Factors in Scaling-up Votators

Seven separate aspects of heat transfer which may be made identical in two different Votators are listed in Table I. Where no reaction or change of phase takes place, it may be required merely to ensure duplication of aspect 2. When a phase change or chemical reaction occurs within the Votator, however, it may be necessary to decide which of the seven aspects of heat transfer should be made the same in the two units as a contribution towards achieving quantitative reproduction of some finished product characteristic. Where two or more aspects are equally effective, the one conforming most closely to production rate requirements is obviously to be preferred.

Suppose, for example, that in laboratory crystallising of a given material the crystal structure controls product consistency and is determined to a considerable extent by

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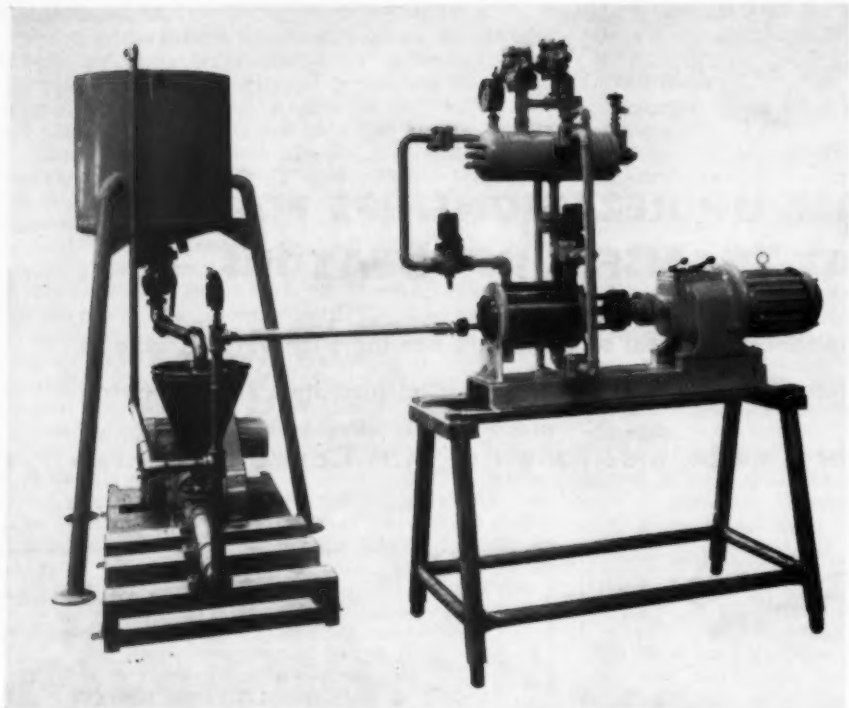

Fig. 1. Pilot-plant Votator and ancillaries for cooling and aerating P.V.C. foam.

a certain pattern of heat transfer in the Votator, then this pattern is a factor which must be reproduced in the large-scale unit for product duplication with regard to consistency.

Derivation of Scale-up Relationships

Making the simplifying assumptions of constant physical properties which stay the same for a given substance in two Votators, Equation (1) becomes:

$$h_s = \varphi\,(D_t^{0.11}\,N^{0.17}\,L^{-0.37}\,\nu^{0.4}) \qquad \ldots.(2)$$

The Prandtl group to the power 0.47 (a possibly hybrid exponent, as discussed elsewhere[1]) is included in the constant, ϕ, which is eliminated in the expression below.

Duplication of Aspect 1 in Two Votators

This requires that:

$$h_{s_1}\,\Delta\,t_1 = h_{s_2}\,\Delta\,t_2 \qquad \ldots.(3)$$

substituting for h_{s_1} and h_{s_2} in terms of Equation (2) and rearranging:

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \left(\frac{D_{t_2}}{D_{t_1}}\right)^{0.11}\left(\frac{L_1}{L_2}\right)^{0.37}\frac{\Delta t_2}{\Delta t_1}\left(\frac{\nu_2}{\nu_1}\right)^{0.4} \qquad \ldots.(4)$$

Duplication of Aspect 2 in Two Votators

$$\text{Total heat transferred/lb.} = \frac{Q}{W} = \frac{h_s\,\pi\,D_t\,L\Delta t}{\frac{\pi}{4}\,(D^2_t - D^2_s)\nu\,\rho} \qquad \ldots.(5)$$

Equating the R.H.S. of Equation (5) for Votators 1 and 2, substituting for h_{s_1} and h_{s_2} in terms of Equation (2) and rearranging:

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}}\left(\frac{D_{t_2}}{D_{t_1}}\right)^{1.11}\left(\frac{L_2}{L_1}\right)^{0.63}\frac{\Delta t_2}{\Delta t_1}\left(\frac{\nu_1}{\nu_2}\right)^{0.6} \qquad \ldots.(6)$$

Duplication of Aspect 3 in Two Votators

The time spent by 1 lb. of material in a Votator is L/v, so that with Equation (5),

$$\text{rate of heat transfer/lb.} = \frac{hs\,\pi\,D_t L\,\Delta\,t}{\frac{\pi}{4}\,(D^2_t - D^2_s)\,\nu\rho}\,\frac{v}{L} \qquad \ldots.(7)$$

Equating the R.H.S. of Equation (7) for Votators 1 and 2, substituting for hs_1 and h_{s_2} in terms of Equation (2) and rearranging:

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}}\left(\frac{D_{t_2}}{D_{t_1}}\right)^{1.11}\left(\frac{L_1}{L_2}\right)^{0.37}\frac{\Delta t_2}{\Delta t_1}\left(\frac{\nu_2}{\nu_1}\right)^{0.4} \qquad \ldots.(8)$$

Duplication of Aspect 4 in Two Votators

Equations (4) and (6) must be satisfied simultaneously. Equating the R.H.S. of Equations (4) and (6) and rearranging,

$$\frac{\nu_2}{\nu_1} = \frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}}\,\frac{D_{t_2}}{D_{t_1}}\,\frac{L_2}{L_1} \qquad \ldots.(9)$$

substituting for ν_2/ν_1 in Equation (4) and rearranging,

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \left(\frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}}\right)^{0.4}\left(\frac{D_{t_2}}{D_{t_1}}\right)^{0.51}\left(\frac{L_2}{L_1}\right)^{0.03}\frac{\Delta t_2}{\Delta t_1} \qquad \ldots.(10)$$

Duplication of Aspect 5 in Two Votators

Equations (4) and (8) must be satisfied simultaneously. Equating the R.H.S. of Equations (4) and (8) and rearranging:

$$\frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}}\,\frac{Dt_2}{Dt_1} = 1 \qquad \ldots.(11)$$

With Equation (11) satisfied, relations between N, v and Δt are given by Equation (4).

DUPLICATION OF ASPECT 6 IN TWO VOTATORS

Equations (6) and (8) must be satisfied simultaneously. Equating the R.H.S. of Equations (6) and (8) and rearranging:

$$\frac{L_1}{v_1} = \frac{L_2}{v_2} \qquad \ldots.(12)$$

and using Equation (12) in Equation (6):

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \frac{D^2_{t_1} - D^2_{s_1}}{D^2_{t_2} - D^2_{s_2}} \left(\frac{D_{t_2}}{D_{t_1}}\right)^{1.11} \left(\frac{L_2}{L_1}\right)^{0.03} \frac{\Delta t_2}{\Delta t_1} \qquad \ldots.(13)$$

DUPLICATION OF ASPECT 7 IN TWO VOTATORS

Inspection of the requirements for duplication of aspects 4, 5 and 6 shows that if Equations (11) and (12) are fulfilled then Equation (9) is satisfied and Equations (4), (10) and (13) become identical, simplifying to

$$\left(\frac{N_1}{N_2}\right)^{0.17} = \left(\frac{D_{t_2}}{D_{t_1}}\right)^{0.11} \left(\frac{L_2}{L_1}\right)^{0.03} \frac{\Delta t_2}{\Delta t_1} \qquad \ldots.(14)$$

(in Equation (4), $(v_2/v_1)^{0.03} = (L_2/L_1)^{0.03}$ when Equation (12) is satisfied). Aspect 7 will be prevailing under these conditions.

Comments

Application of the scale-up relationships is seen to depend to a considerable extent on accurate prediction of $\Delta t_2/\Delta t_1$. This is sometimes not easy, as, for example, when cooling materials undergoing a phase change and which are capable of substantial supercooling. The value of $\Delta t_2/\Delta t_1$ is quite often near to unity. Alternatively, if any experimental values are available of *overall* Δt and overall coefficients of heat transfer for the two units operating somewhere near the required conditions, these may be used with h_s values from Equation (1) for closer estimation of Δt_1 and Δt_2 across the scraped films by usual methods.[2] Preliminary runs based on these calculations should then provide information for a closer estimate of $\Delta t_2/\Delta t_1$, leading to a more accurate scale-up. Within the relevant flow régimes, Equation (2) shows $h_s \propto N^{0.17}\ v^{0.4}$, so that considerable variations in predicted or scaled-up shaft speeds or flow velocities correspond to much smaller variations in heat transferred. This scale-up treatment has dealt only with heat transfer and has not been concerned with other factors which may influence product properties—for example, mass-transfer conditions within the Votator or any processing of the material beyond the Votator.

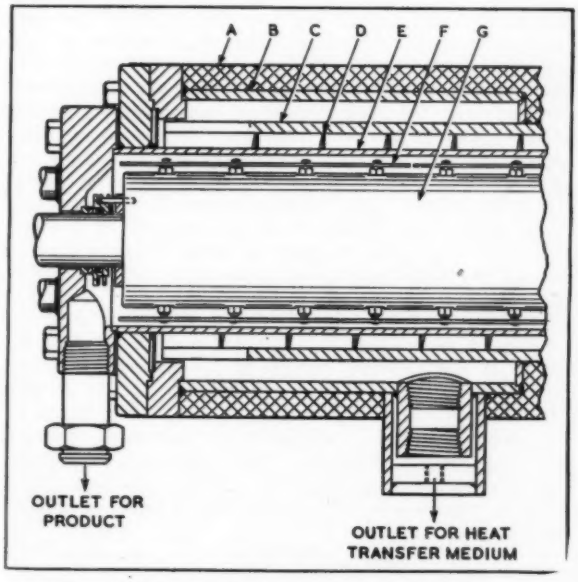

Fig. 2. Constructional details of a Votator heat exchanger. (A) insulation; (B) section for outlet; (C) outer tube heating or cooling medium; (D) spiral baffle; (E) inner tube for product; (F) scraper blades; (G) rotating shaft

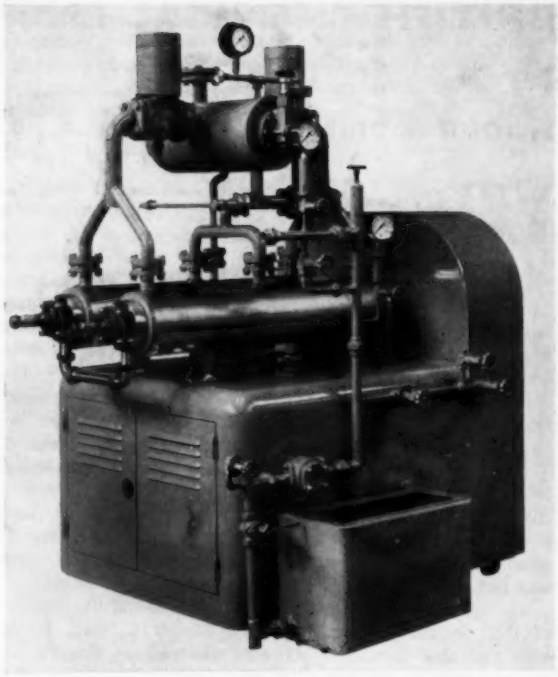

Fig. 3. Twin-cylinder production model for chilling lard. Direct cooling by means of Freon is provided.

Conclusions

Using a recent correlation for scraped-film heat transfer in the Votator, scale-up relationships have been derived for particular flow régimes, enabling any of seven different aspects of heat transfer to be duplicated in two Votators of differing dimensions but of a certain conventional design. These relationships are summarised in Table II below.

TABLE II—APPLICATION OF SCALE-UP EQUATIONS

Aspect of heat transfer to be duplicated (see Table I)	Scale-up relationships to be satisfied
1	Equation (4)
2	,, (6)
3	,, (8)
4	Equations (9) and (10)
5	,, (4) and (11)
6	,, (12) and (13)
7	,, (11), (12) and (14)

ACKNOWLEDGMENT

Figs. 1, 2 and 3 are by courtesy of A. Johnson & Co. (London) Ltd.

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BRITISH CHEMICAL ENGINEERS — A PERSONAL CRITIQUE

by JOHN A. ORIEL, C.B.E., M.C., M.A., B.Sc., F.R.I.C., M.I.Chem.E.

VERY many of those who are concerned with the development of technology in this country and who are aware of the great importance attached to the teaching of chemical engineering in other countries must have read with alarm the first Annual Report of the National Council for Technological Awards. In this report only two courses in chemical engneering appear to have been approved by the National Council as qualifying for the correct standard of training for the Dip. Tech. (Eng.). The alarm created must be even greater when it is realised that, although two courses are mentioned, they are but two variants of the same course at Battersea College of Technology, and that in fact there is only one technical college recognised as capable of teaching chemical engineering to the required standard in this country. Such a state of affairs must give rise to several questions. In what follows the writer is stating his own personal views and not those of any institution, industry or company.

The questions to be asked are: What is the likely effect of this on the prosperity of the country? What is the cause of this shortage? Are we alarmed at this or are the universities dealing with the situation satisfactorily? Finally, what ought to be done if there is any need to repair this state of affairs?

The Country's Prosperity

First, what is likely to be the effect on the prosperity of this country? It is becoming wearisome to point out comparisons between the technology of this country and that of Russia and America, but a glance at the proportion of chemical engineers trained in those two countries will dispose of any argument as to whether those countries find the need for large numbers of chemical engineers important. Leaving that aside, therefore, as being a fact that ought to be too well known to be reiterated here, we turn our attention to our own country. Here within the last few months Sir Alexander Fleck's report on the Atomic Energy Authority ought to be a cause for thought. In this, for the first time, it is suggested that we slow down our operations in the field of the production of atomic energy solely on account of the fact that we do not have enough technologists to operate the plant. Of all technologists qualified to operate plant of this sort the chemical engineer stands out as the most likely, and it has been estimated that this country needs something between 1200 and 1500 chemical engineers every year for some years to come. In fact, in spite of the rapid increase over the past few years, the numbers actually being turned out in total at present are not more than 300. Sir John Cockcroft has continuously appealed for more and more engineers capable of translating scientific developments into workable processes. Whilst there is no doubt that we need physicists and mechanical and electrical engineers in certain parts of the development of the Atomic Energy Authority, the man mainly in demand for the development of the processes—the man who knows his basic sciences combined with problems of fluid flow, heat transfer and the rest—is the chemical engineer. Therefore, even in this new industry alone, the shortage of chemical engineers must have a very serious effect on the future prosperity of this country. It would really be labouring the point if we went on to think of other industries that use chemical engineers whenever they can get them—for instance, the chemical industry itself in its many aspects and the petroleum industry.

Cause of the Shortage

If this is such an urgent affair, why is there only one technical college where courses leading to the Dip. Tech. (Eng.) can be taught? The cause is a simple one; there are too few teachers. This, of course, can be attributed to some extent to the fact that every good chemical engineer can be attracted into industry, and it is only those chemical engineers who feel almost a passion for teaching and the academic life who will leave industry for the college. There are a number of these people, fortunately, but not nearly enough to go round. The problem could be overcome by lowering the standard, but it would be no service to the country to lower the standard of those capable of teaching to the highest possible requirement. There are men capable of teaching to the lower standards—in chemical engineering, standards which are required for operators and technicians—but the Dip. Tech. (Eng.) is at least supposed to be up to the standard of a first- or second-class honours. One cannot teach to this standard unless one is well beyond this standard oneself, and the number of men who fulfil this requirement are very few. The men in this country who can teach to this standard are already occupied at the universities.

Owing possibly to its history, the technical college never has had in this country the same prestige as the university. The technical college did not start life as it did on the Continent—in order to train technical managers —but with the very laudable object of attempting to teach apprentices and craftsmen how better to do their jobs. The result is that the technical colleges have always been, and still are, the poor cousins of the universities in this country. One or two who have established a cross-linkage, as it were, with the universities—such as Edinburgh, Glasgow and Manchester—succeed because of their affiliation in establishing a higher prestige value. Teachers are not kept away from technical colleges because of a lower standard of pay, but because of difficulties they meet in connection with possibilities of research and the number of hours they have to put in at teaching.

Furthermore, having established eight Colleges of Advanced Technology, it is essential that we should build these up into technical colleges of the highest rank, comparable with those on the Continent. In order to do this, the Ministry of Education and the local education authorities should be prepared to put everything that they have for the time being into these eight colleges, instead of, as at present, spreading the available teaching ability over a large number of colleges which have an entirely different job to do.

University Situation Brighter

The picture at the universities is much brighter. Since the war several Chairs of Chemical Engineering have been set up, and although there was quite a beginning

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Mr. Oriel, *the past president of the Institution of Chemical Engineers, has always been keenly interested in the welfare of chemical engineers, as reference to Vol.* 33, *No.* 2, *of the* Transactions *for* 1955 *will show.*

before the war, particularly in London University, a real effort has been made since the war to establish chemical engineering in our universities. The first real attempt after the war was made by the Shell Company giving sufficient funds—nearly half a million pounds—to Cambridge University to establish the Department of Chemical Engineering, and of those pioneers in this subject who first set up this Department four are now occupying Chairs in other universities. This was followed very quickly by the establishment of the Courtauld Chair of Chemical Engineering at Imperial College.

There are thriving Departments in Birmingham, Durham, three London colleges, Sheffield and Swansea and the Departments loosely attached to Edinburgh, Glasgow and Manchester Universities; there are also other readerships in chemical engineering attached to Departments of Fuel Technology and the like at other universities. This is in fact excellent and will be a very substantial help if given suitable encouragement. The difficulty with the universities, of course, is that they are quite rightly concerned more with the basic sciences and with research than with the application of scientific developments. If one could once more compare the teaching in our universities and technical colleges with that of the Continent, the difference is that in the continental "universities of technology" the subjects are taught with a background of their ultimate use, both in the basic sciences and the technological subjects.

What is to be Done?

What, then, can be done? Quite clearly a complete change of heart and a very different approach to the subject is necessary. It is impossible now to suggest that this country embarks on a large establishment, as we should have done long ago. The reason for abandoning any such project now is not shortage of money but, as stated earlier, the lack of availability of teaching staff. Now we must concentrate on the best of what we have rather than spread our available teaching talent too thinly over a multitude of technical colleges. As I have already suggested, the Ministry and the local education authorities should now concentrate on making the eight Colleges of Advanced Technology into colleges of which we can really be proud, and raising them to the high standard in applied sciences that our universities hold in the pure sciences throughout the world.

Heat Transfer Temperature and Velocity Distribution

NEW equations have been proposed by TADEUSZ HOBLER for the distribution of velocities and temperatures in tubes at flows ranging from streamline through transitional and up to turbulent flow at Reynolds number values of 10^6.

For the velocity distribution, the following correlation is proposed:

$$\frac{V}{V_o} = \frac{2\,\frac{Y}{R}}{1-\left(1-\frac{Y}{R}\right)^{n}\cdot\psi} - \left(\frac{Y}{R}\right)^2$$

In this, the function ψ is defined as:

$$\psi = 1 - \frac{32}{f\,.\,\mathrm{Re}}\cdot\frac{V_o}{V_m}$$

From experimental results, the following relation has been obtained for the exponent n:

$$n = 2.7\,\frac{\frac{Y}{R} + 0.2\,(\psi - 0.9)}{\frac{Y}{R} + 0.02}$$

TEMPERATURE

A similar relationship has been obtained for the temperature distribution where the Prandtl number is 1.

$$\frac{\theta}{\theta_o} = \frac{2\,\frac{Y}{R}}{1-\left(1-\frac{Y}{R}\right)^{m}\cdot\varphi} - \left(\frac{Y}{R}\right)^2$$

where m is defined by an expression similar in form to that for the exponent in the expression for velocity distribution:

$$m = 2.7\,\frac{\frac{Y}{R} + 0.2\,(\varphi - 0.9)}{\frac{Y}{R} + 0.02}$$

The following expression for φ has been obtained analytically.

$$\varphi = 1 - \frac{4}{\mathrm{Nu_1}}\cdot\frac{\theta_o}{\theta_m}$$

$\mathrm{Nu_1}$ is the Nusselt number based on a Prandtl number of 1.

However, a more generalised equation which covers the three zones up to $\mathrm{Re} = 10^6$ for temperature distribution may also be written in the form adopted by COLBURN $\left(\mathrm{St}\,.\,\mathrm{Pr}^{\frac{2}{3}} = \frac{f}{8}\right)$, namely:

$$\mathrm{St}\,.\,\mathrm{Pr}^{1-B} = \frac{f}{8}\left[\frac{\theta_o}{\theta_m}\cdot\frac{V_m}{V_o}\right]\left[\frac{1}{1+\left(\frac{32\,V_o}{f\,.\,\mathrm{Re}\,.\,V_m}\right)^2}\right]$$

In these equations, the symbols have the following meanings.

B = a constant of value 0.4 for turbulent range, 0 for streamline range and 0.33 for transition range;
f = Fanning friction factor;
Pr = Prandtl number;
R = tube radius (m.);
Re = Reynolds number;
St = Stanton number;
V = local linear velocity at distance Y from wall (m./sec.);
V_m = mean linear velocity (m./sec.);
V_o = maximum linear velocity at centre of tube (m./sec.);
Y = distance from wall (m.);
$\theta = t - t_w$ where t = local temperature (°C)
t_w = wall temperature (°C); and
$\theta_o = t_o - t_w$ where t_o = temperature at centre (°C).

Details of the derivation of these equations and methods of applying them in the three ranges of flow are given in a paper by TADEUSZ HOBLER in *Chemia Stosowana*, 1957, **1**, 1, 21, from which the above have been abstracted. The symbols have been changed in some cases to conform with Anglo-American conventions. *Chemia Stosowana* is a new quarterly devoted to chemical technology and chemical engineering published by the Polish Academy of Sciences in Wroclaw.

AMERICAN LETTER

Developments in Weighing and Batching

IN most processes, one or more weighing or batching operations will be found and American manufacturers offer a wide choice of equipment for this purpose. These machines range from simple platform-type scales to continuous self-checking devices and elaborate programme-weighing installations. Several factors, such as the tightening of quality standards, the continued quest for increased automatic control and the introduction of industrial transducers have virtually revolutionised many branches of the weighing machine industry during the last decade. Since the chemical engineer is frequently asked to specify the weighing equipment to be used at various points in a process, he must be able to balance technical possibilities against likely economies of new developments in this field. Detailed below are a number of new equipments by American manufacturers.

Newer Sensing Mechanisms

The classic knife edge and fulcrum support principle, although capable of sustained accuracy with careful use, has several drawbacks when applied to certain types of industrial measurement. Hence, it is not surprising that some more recent weighing devices use entirely different principles, such as torsion bars, flexure plates, null-balance pneumatic cells and transducers of the electrical strain gauge type. Flexure plates, as adopted by the Thayer Co., enable a magnifying leverage system to be constructed free from pins and pivots, but rigid enough to maintain accuracy under millions of shock loads; even under a 200-lb. load the movement of the platform or its equivalent is only 0.003 in. Similarly, in the null-balance pneumatic load cell, as made by Weighing & Control Components Inc., the applied load moves only 0.005 in. If electrical strain gauges of the piezo or resistance type are employed, as made by a number of concerns, such as Baldwin or Fairbanks-Morse, the actual movement may be negligible. This means that, instead of a delicately mounted mechanism vulnerable to dirt, shock and wear at several points, the whole assembly can be made virtually rigid and a new range of equipment immediately becomes possible.

Modern Scale Designs

Although weighing equipment in general may be divided into three main classes—continuous, automatic or continuous batch, and unit weighers—the choice of the optimum machine may depend not upon the process but upon the degree of accuracy required for the scale.

Continuous Weighing. Continuous weighing and gravimetric proportioning equipment has been developed to a degree far removed from the old stirrup roller and conveying-band principle but, nevertheless, a guarantee from the makers of an accuracy better than $\pm 1\%$ is often very difficult to obtain. Generally, this is not because of limitations in the sensing mechanism, but arises from physical variations in the material, such as the feed rate and the bulk density. In this type of machine, the entire weigh-belt mechanism may be carried by the scale assembly or sensing element, so the net weight per period becomes a function of the belt speed and material depth, as well as the material density. Uniformity of weighing and discharge rate is controlled by means of mechanical, electrical or pneumatic feed-back signals proportional to the net weight. Of course, some device to ensure freedom from flooding must be incorporated, such as a star feeder, as well as a breaker to reduce voiding. These signals control the belt speed, the feed gate, or both. This principle is used by numerous makers, such as Omega, Wallace and Tiernan, and Weighing & Control Components Inc.

Automatic or Continuous Batch-weighing. Rather unexpectedly, weighing by rapid automatic batching cycles can give considerably higher accuracies than continuous weighing, despite the extra shock loads and periodic interruptions. This is largely because a true net weight is measured during each cycle and no interference is experienced by material variations. As a rule, these machines incorporate a weigh hopper attached to a scale or sensing mechanism. The hopper is filled to near-capacity by a rotary or vibratory feeder, which is interrupted by electrical contactors and relays and the exact weight is made up by a small dribble feeder. At this point, electrical contactors cut off the feed, rotate the hopper and reset the machine for the next cycle. Some machines use air signals as an alternative to electrical operation. The weight delivered to the hopper is pre-set on the scale mechanism, while the operating cycle is set by a cycle controller. Remote adjustment, totallising and check-weighing, with high- and low-weight alarms can readily be obtained, so that one or more weighing operations can be fully controlled from a central point.

Such machines are available for outputs of 1 to 100 tons an hour and can be used for materials having bulk densities from 10 to 200 lb. per cu. ft. Guaranteed accuracies of ± 0.1 to 0.2% can be achieved over long periods, and this type of machine can be adapted to measure liquids gravimetrically where volumetric measurement and control are not good enough. Typical current prices are about $4500 for a 2-ton-an-hour solids weigher and approximately $7000 for a 50-ton-an-hour machine (Thayer).

Unit or Batch Scales. Batch scales for both feeding and take-off operations have also been greatly improved, as regards speed and accuracy. One recent model, the Thayer CD2OX, is designed to weigh 50,000 grammes to within ± 1 gramme, i.e., $\pm 0.002\%$. The Selectrol automatic check-weigher, which uses optical projection, is also capable of high accuracies, from one part in 5000 to one part in 20,000, i.e., 0.02% or 0.005%, according to need. Some check-weighers include automatic rejection and alarms as well as integrators and can be used in almost any production line. Even standard, rapid bagging machines such as made by Bemis, the Exact Weight Co., and Howe, are said to give consistent accuracies within 0.15 to 0.2% for rates up to 25 100-lb. bags a minute. Weighing at this order of accuracy and speed can effect considerable economies over older hand-weighing methods.

Some firms, such as Richardson, have developed complex weighing systems whereby batches incorporating up to 20 components can be accurately formulated by means of an automatic programme controller. These systems are particularly suited to the rapid compounding of plastic, rubber and paint stocks prior to blending, as well as preparing mixes for foodstuffs and chemicals. Formulations can be changed at will by resetting the master programme controller which can be used to provide inventory records and perform other functions. Such machines, without doubt, will be integrated into the fully automatic plants of the future.

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VOLUME OF LIQUID IN A CONE

by D. B. PURCHAS, B.Sc., A.M.I.Chem.E.

This nomogram gives the volume of liquid in a conical-bottomed vessel, all the liquid present being contained in the cone. The volume, V, is thus given by:

$$V = \tfrac{1}{3}\pi\,(d/2)^2\,h$$

But, $d/h = \dfrac{D}{L}$

Hence, $V = \dfrac{\pi}{3}\dfrac{D^2h^2}{L^2}$

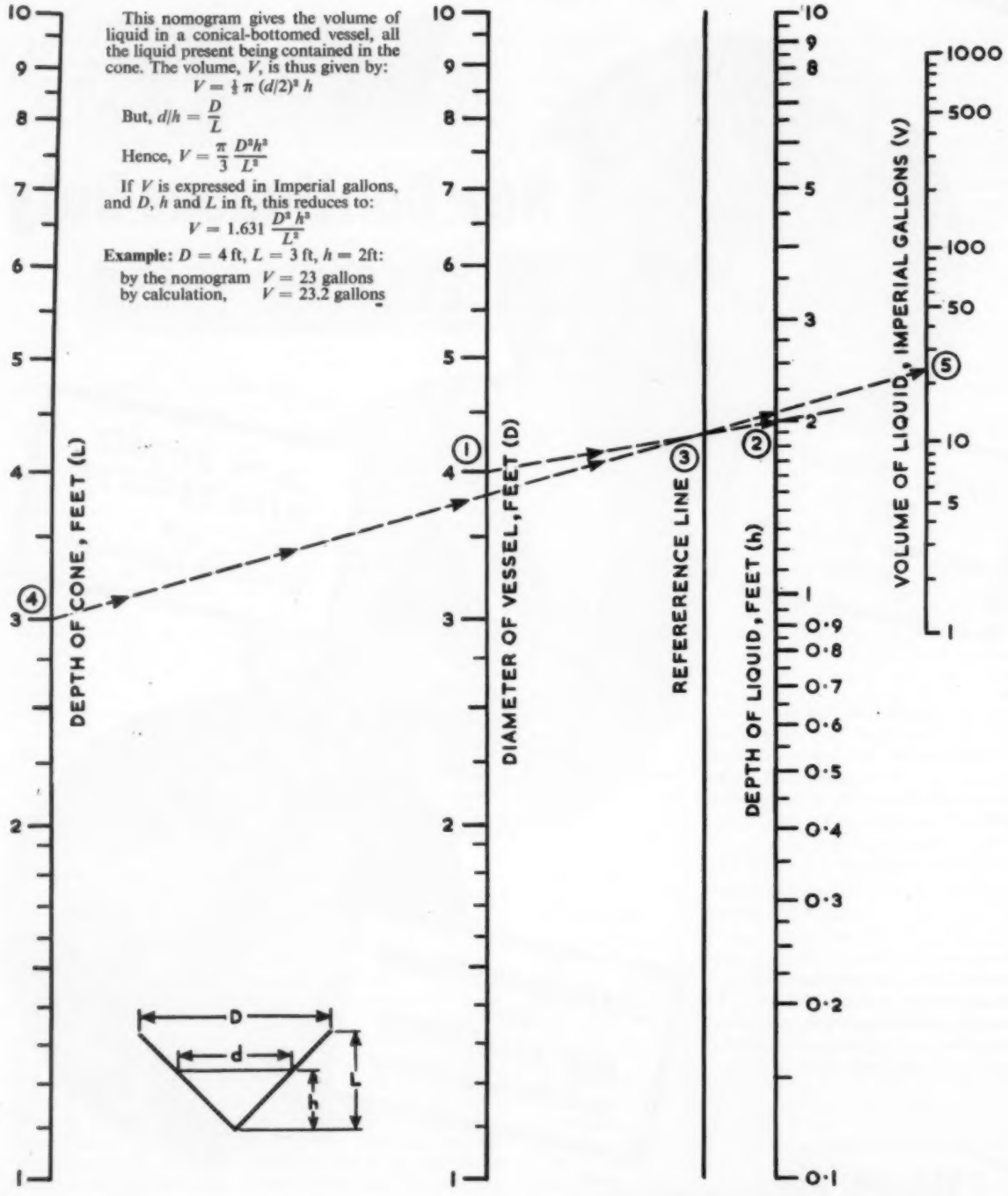
If V is expressed in Imperial gallons, and D, h and L in ft, this reduces to:

$$V = 1.631\,\frac{D^2\,h^2}{L^2}$$

Example: $D = 4$ ft, $L = 3$ ft, $h = 2$ft:

by the nomogram $V = 23$ gallons

by calculation, $V = 23.2$ gallons



British Chemical Engineering
NOMOGRAM NO. 25

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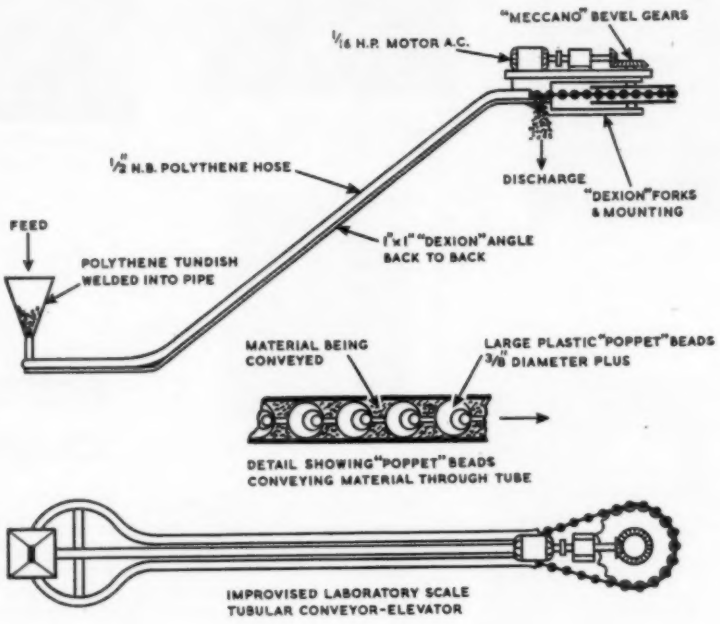
P.1451

PROCESS ENGINEER'S NOTEBOOK

Laboratory Pilot Plant Conveyor Elevator

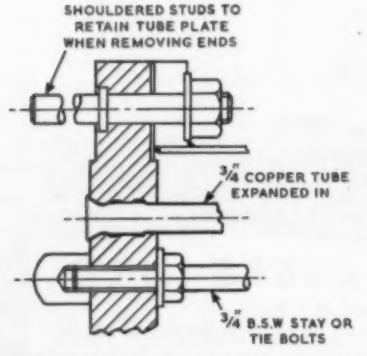
A CONSTANT FEED of a corrosive and abrasive slurry was required from a bunker to the feed to a ball mill. As nothing suitable was available at this small scale from the conveyor elevator manufacturers, it was necessary to improvise a small conveyor elevator for the job; and so successful was the performance and capacity of the improvised conveyor that attempts were made to interest possible suppliers.

The pilot-scale conveyor elevator consisted essentially of ten links of plastic "poppet" beads drawn through a length of polythene tube of ½ in. nominal bore. The drive was constructed from Meccano bevel gearing; the driving head was actually filed out from a Meccano pulley. Motive power was by means of a small vacuum cleaner motor of fractional horsepower. A small polythene tundish welded into the polythene pipe provided the feed point. It is within the realms of possibility that the unit could be scaled up to provide a plant-size elevator conveyor, provided properly designed "poppet" beads could be manufactured. The advantages that the small unit displayed—such as (1) resistance to corrosion and abrasion; (2) flexibility; either horizontal or vertical conveying in two planes; (3) minimum structural supports required; and (4) no wearing parts but very easy maintenance, capable of easy extension or contraction—could then be repeated on a much larger scale.


"MECCANO" BEVEL GEARS
1/16 H.P. MOTOR A.C.
½" N.B. POLYTHENE HOSE
DISCHARGE
"DEXION" FORKS & MOUNTING
FEED
POLYTHENE TUNDISH WELDED INTO PIPE
1"×1" "DEXION" ANGLE BACK TO BACK
MATERIAL BEING CONVEYED
LARGE PLASTIC "POPPET" BEADS ⅜" DIAMETER PLUS
DETAIL SHOWING "POPPET" BEADS CONVEYING MATERIAL THROUGH TUBE
IMPROVISED LABORATORY SCALE TUBULAR CONVEYOR-ELEVATOR

Heat Exchanger Modified by the Use of Plastics

FAILURES OF HEAT EXCHANGERS in chemical plants often occur through corrosion. Although plastics possess valuable corrosion-resisting properties, the fact that they generally have low thermal conductivities and cannot resist high temperatures means that their use in heat exchangers is limited. Frequently, I think, corrosion originates from the formation of scale on various parts of a heat exchanger. It was found in a particular application that in a condenser employed for mixing organic-inorganic solutions that the corrosion occurred through electrolysis. This took place where the tubes entered the tube plates and also where they passed through the baffles or support plates. Since the phenol formaldehyde of thermo-setting resins impregnated on a linen base was found to have good resistance to the chemicals cooled by this condenser, it was decided to adopt a construction which employed tube plates, baffles and support plates of this material. These replaced the metallic components used originally. The copper tubes which had satisfactory corrosion resistance for this application were rolled straight into the tube plates in the usual way; protective brass ferrules were not found necessary.



SECTION OF PLASTIC TUBE PLATE
SHOWING SUITABLE METHOD OF FITTING TUBES & STAYBOLTS

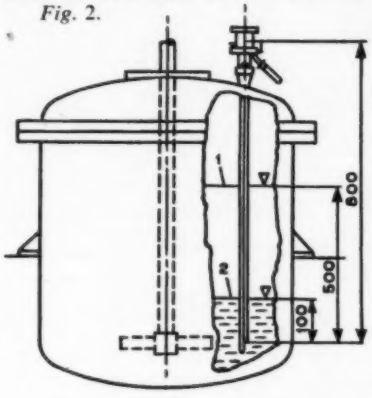
The modified condenser was found to have very satisfactory resistance to corrosion and the additional cost of the plastic components more than offset the cost of replacement and maintenance which had been the case previously. The plates were designed with a safety factor of 10 and the materials used were laminated linen or cotton, phenol-formaldehyde sheet with a tensile strength of 25,000 psi or asbestos-filled material with a tensile strength of 23,000 psi.

F.W.M.

Sampling from a Vessel under Vacuum

THE DEVICE DESCRIBED here avoids the necessity to break the vacuum when a liquid sample has to be extracted from a vessel operating under vacuum. Air from the atmosphere is introduced into the air lift by means of needle valve (6) and it passes through tube (4) to the jet (5) fitted inside the lift tube (3). The air thus fed into the vessel lifts liquid from it to the sampling head, where it is collected in the annular space and can be turned back to the vessel or to the sampling bottle (9). The sampling vessel may be detached from the sampling head by means of the valve (7) or by the closure of an opening in the sampling head.

Fig. 2.

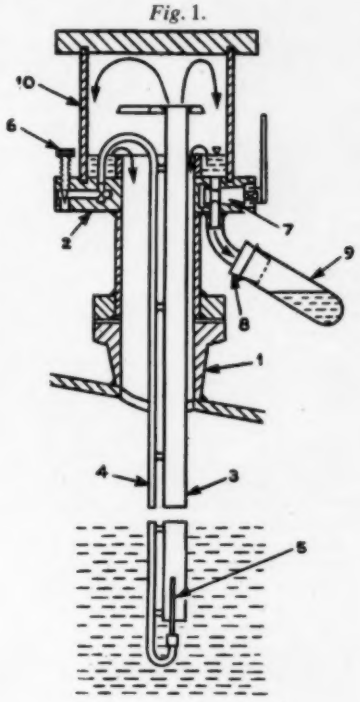


It is recommended that the volume of the sampling container be kept as small as possible so that it can be evacuated in a few seconds. It is necessary for the end of the air pipe (5) to project for some distance into the tube (3) in order to prevent the escape of air back into the reaction zone. The best results are obtained by admitting a minimal quantity of air, otherwise the device will stall.

When the sampling head is fitted with an inspection port the device can be used to study qualitatively physical changes taking place in the reacting liquids; for example, colour, clarity, viscosity and solid formation may be noted. It has been used successfully for liquids of viscosities up to 400 cps.

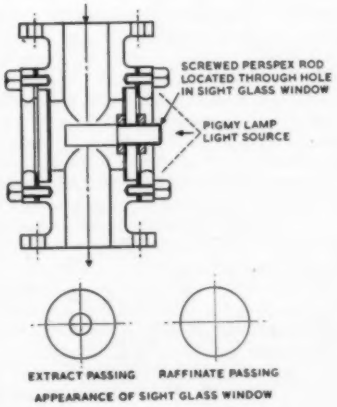
It is important that the sampling valve (7) gives a dead-tight shut off, and that the apparatus, if it is an inspection glass, is fitted well clear of the vessel. This is to reduce thermal shock. The best method of fitting the device is shown in Fig. 2, where (1) keeps the normal liquid level in the vessel and (2) the lowest level in the vessel at which the sampler will work. The dimensions given in Fig. 2 are in mm.

Fig. 1.



Sight Glass for Interface Detection

IN THE CHEMICAL purification of mineral, vegetable and coal tar oils, it is customary to wash batchwise first with sulphuric acid and then caustic soda to derive the refined oil. After the washing treatment, which is generally performed in a conical bottom tank provided with some means of agitation, the contents are allowed to settle and the bottom layer containing the extracted impurities is run off, leaving the refined oil to be pumped away either for processing or to storage. The extract layer is run off from the bottom of the conical tank via a valve and sight glass and the valve closed immediately the interface appears in the sight glass. This, however, is in practice a far from simple operation, since the aqueous bottom layer has extracted so many of the darker coloured impurities from the oil that the detection by colour of the interface is frequently very difficult. The modification to a standard sight glass has, however, permitted this operation to be performed with complete safety and satisfaction.


SCREWED PERSPEX ROD LOCATED THROUGH HOLE IN SIGHT GLASS WINDOW
PIGMY LAMP LIGHT SOURCE
EXTRACT PASSING
RAFFINATE PASSING
APPEARANCE OF SIGHT GLASS WINDOW

The light is transmitted from the end of the perspex rod through a thin film of the solution. The distance of the end of the rod from the sight glass is found by trial in test tubes in the laboratory and should be such that the light transmitted through the thin film of extract is extinguished by the same thickness film of raffinate. The separation is therefore distinct and the interface observed when the light spot in the centre of the dark glass disappears.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Chinese Chemical Targets

The target of capital investment in Chinese chemical projects for 1958 is 500 million yuan (£72.6 million), and the new plants will include a synthetic rubber factory and a pharmaceutical plant. Bulk production of penicillin and streptomycin is to begin in the country and aureomycin will be supplied by the No. 3 Pharmaceutical Works. Nearly half of the capital investment of the chemical industry will be allocated to fertiliser plants and trial production will begin of urea, double superphosphates and nitrogen-potassium fertilisers. The oil production target of 1,550,000 tons includes totals for crude petroleum, crude shale oil, oil from low-temperature carbonisation of coal and synthetic crude. Of the crude, 56% will be natural. The refinery at Tushantzu will be expanded to an annual production capacity of 400,000 tons of crude, and a new refinery is to be built in the Tsaidam basin and the existing refinery expanded. The shale-oil-producing centre at Fushun is to be enlarged and a further shale-processing combine established with oil refineries in Kweichow and Shansi to produce motor fuels by low-temperature carbonisation of coal and the Fischer-Tropsch process. A refinery is planned in Szechwan for the production of synthetic fuels from natural gas.

Bulk production will begin of low-heat cement, oil-well cement and high-early-strength cement, and experimental production will begin of high-strength cement, expansive silicate cement, expansive aluminate cement and high magnesium oxide cement. Work will continue on three new cement plants in Szechwan, Shansi and Honan, two of which will be provided by Eastern Germany. Three new plants will be begun in Kweichow, Anhwei and Chekiang, the latter two having a combined annual capacity of 300,000 tons. Trial production will begin of asbestos cement pipes and reinforced concrete pipes. Other plans provide for the experimental production of glass fibre and of glass piping for the food and chemical industries and for starting a new glass plant in Honan.

Low Pressure Plastics In Germany

A plant for the manufacture of low-pressure polyethylene is to be built in 1959 at the Hüls Co.'s chemical works having a capacity of 500 tons monthly of various types of Vestolen. The plant has been so designed that it will be possible without additional capacity to turn it over in the shortest space of time to any of the manifold products which it can manufacture. For the past two years there has existed a close exchange of experience of the Ziegler process operated by Hibernia Co. and Hüls, and the experience will be reflected in the full-scale plant design. Both companies have erected pilot plants and Hüls have taken over the output of both for development of its technical application. Since operation commenced in 1956, the capacity of these pilot plants has been increased from 30 to 100 tons per month. The sales and technical service for the low-pressure polyethylene emanating from the Gelsen Kirchen-Buer works of Scholven Chemie will also be carried out by Hüls. The product, at the same time, will be sold under the trade-name Vestolen. A further licence has been acquired by Hüls for the manufacture of polypropylene, again by the Ziegler process. The researches on this material are progressing so well that sample quantities will be available in the foreseeable future.

Agricultural Chemicals

Fisons Pest Control Ltd. and the Geigy Co. Ltd. of Manchester, sole concessionaires in the United Kingdom of J. R. Geigy, S.A., of Basle, Switzerland, have concluded an agreement by which the entire range of Geigy agricultural and horticultural products, apart from DDT, will now be marketed in the U.K. by Fisons Pest Control.

In Holland, Delta Chemie, a joint establishment of the First Netherlands Cooperative Fertilizers Works E.N.C.K., and the National Cooperative Trading Association for Agriculture, "Centraal Bureau", Rotterdam, has been established at Vlaardigen to manufacture mixed fertilisers, insecticides and other chemical products. Plans are in hand to start the production of fertilisers for the international market.

German Chemicals from Coal

In the past year the coal chemicals industry of West Germany has been working at full capacity, because the carbonising industry, confronted with the need to meet the continuing expansion of the steel industry, has worked at greater capacity than hitherto. Coke output in 1957 was 45.2 million metric tons, which represents a 4.1% increase over the output for the previous year. Crude tar production amounted to 1.96 million tons—an increase of 3%—and crude benzol 565,000 metric tons—an increase of 3.3%. Ammonia was produced to the tune of 111.000 metric tons of nitrogen (a 3.7% increase over 1956) and 23.5 milliard cu. m. of gas (a 4.9% increase). Plants working the Fischer-Tropsch process produced 54,000 tonnes (6% increase) and the brown coal and shale oil plants yielded 155,000 tonnes of mineral oil products. Although there appeared to be a falling off in the rate of investment in the coal industry, the coking industry extended its plant. For example, the Rheinelbe Mining Co., on the site of the Srachtanlage Zollverein, erected a new coking plant with a daily output of 2500 tonnes of coke from the first extension. Mannesmann A.G. at its Hückingen works built a coking plant with a 2700 tonnes per day capacity. The Dortmund Mining Co. erected a benzol pressure recovery plant to the designs of Adolph von Hausemann. This plant has a monthly capacity of 4500 tonnes. At its chemical works at Carolinenglück the Bochum Mining Co. has commissioned a new phenol plant. Among other plants recently commissioned is a high purity naphthalene plant employing the Rutger process, which is now in operation at the tar distillation works of the Ewald-König Ludwig Mining Co. Finally, the Tar Utilisation Co. recently extended its capacity for extracting chemicals from coal tar.

German Chemicals Output

Output of West Germany's chemical industry as a whole in 1957 amounted to £1464 million, an 11.4% increase over 1956. Plastics production rose to 589,000 tons—up 22%. The export ratio increased 2% to 25.

Activities of the Kuhlmann Establishment

The receipts of this group of companies exceeded 17,518 million francs in 1950, 29,682 million francs in 1955 and, by 1956, had reached the figure of 31,058 million francs. The tonnage of material sold increased from 1,014,600 tonnes in 1950 to 1,218,000 tonnes in 1956. The average value of the manufactured products has increased appreciably during the past years. The receipts of the associated companies of Kuhlmann reached a figure of 8833 million francs in 1956.

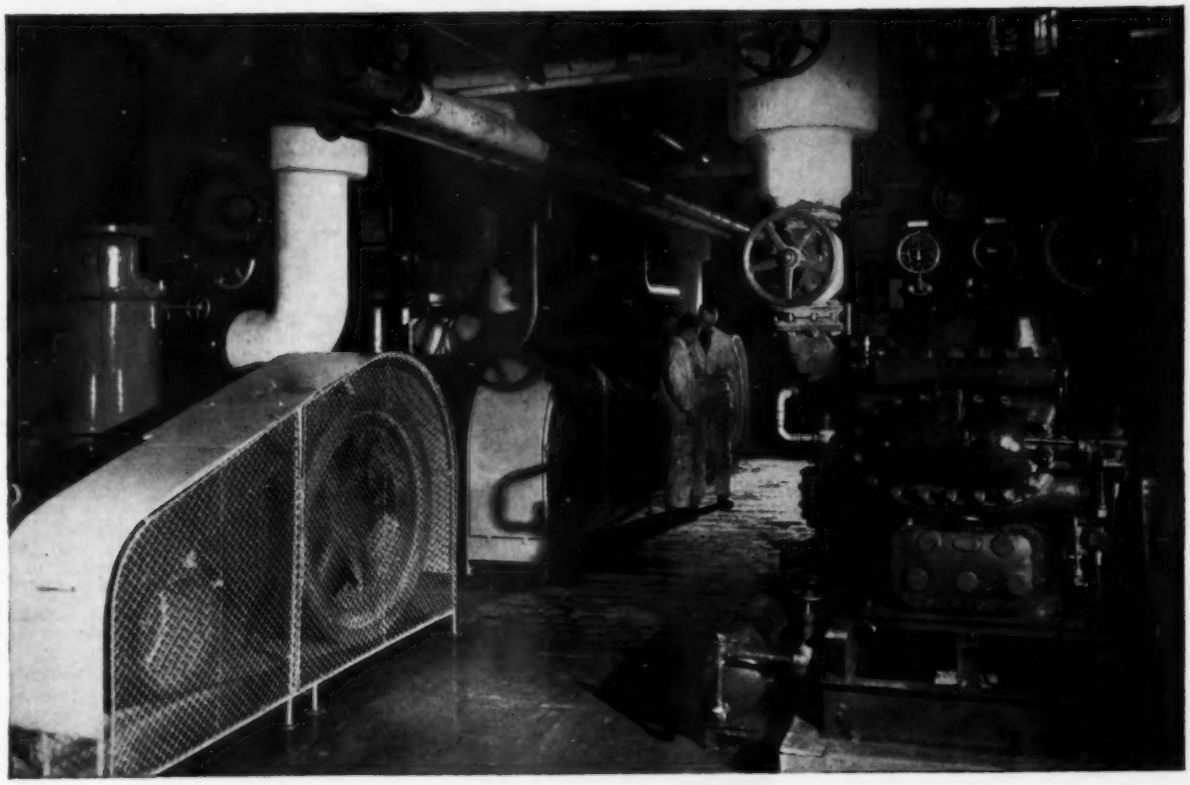
A new nitric acid plant was commissioned in June, 1957; this uses a new process and produces monthly more than 5000 tons of acid as 100% nitric acid. The total nitric acid production in 1956 increased to 130,000 tons. The annual output of derivatives, the olefinic oxides developed in the factory at Chocques, has increased from 1200 tons to 6500 tons during the course of the past ten years. The plant at the site for the oxidation of ethylene has been converted for the oxidation of propylene. A unit for the production of synthesis gas by oil cracking has been erected at Paimboeuf, and Kuhlmann have taken part in the formation of the company "Manufacture Normande de Polyéthylènes", which is to go into production this year.

At Harnes the Société Courrières-Kuhlmann has increased its monthly output of alcohols made by the oxo process for treatment of petroleum-derived olefins to 720 tons a month. A number of modifications to this plant will make possible an output of 1000 tons per month this year. The Société Marles-Kuhlmann, in addition, has constructed at Gonfreville a plant for the production of ethylene oxide and propylene oxide by the direct oxidation route. Another development is the manufacture of polyphosphates and synthetic detergents.

At the end of last year in the field of plastic materials the Société Lorraine-Kuhlmann combined with the Houilleres de Lorraine for the manufacture of polystyrenes. Finally, the Etablissements Kuhlmann, in the field of atomic eergy and in research generally, has stepped up its activities considerably.

BCE 3214 for further information

REFRIGERATION TO MEET THE NEEDS OF MODERN INDUSTRY



THREE THOUSAND HORSE POWER AT THE NEW LYONS MAID FACTORY, GREENFORD

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No less than 3,000 horsepower is employed in the main engine room at the new LYONS MAID factory at Bridge Park, Greenford, one of the biggest plants in the country devoted to entirely to manufacture of ice cream.

Refrigeration is provided by five 8-cylinder V/W compressors, five Vertical Single Acting Booster compressors and two Rotary Booster Compressors, with provision for the installation of additional units at a later date. Over three miles of refrigerant mains are used in this installation which utilises fully 15 tons of ammonia refrigerent to provide all the refrigeration needed for mixing, holding, ageing, freezing and storage in this vast factory.

In addition to its outstanding size and efficiency this installation is remarkable for the exceptionally high standard of the safety precautions that have been designed into the plant.

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Book Reviews

Dangerous Properties of Industrial Materials
by N. Irving Sax
Chapman & Hall, London, 1957, 1476 pp., 180s.

THIS book weighs 6 lb., has 1476 pages, is 3 in. thick, and costs £9 in Britain. It is the second edition of SAX's "Handbook of Dangerous Materials", published in 1951. Its intent, according to the front cover, is to provide a convenient reference book to enable chemists, engineers or non-technical personnel to find out quickly whether a substance is potentially dangerous and what precautionary measures must be taken. By and large, it succeeds in its intention.

The book centres round about 1000 pages which deal alphabetically with nearly 9000 materials, mostly industrial chemicals. For each of them, from abietic acid to zirconyl sulphide, a synopsis is given of the more important properties of the material which may influence its safe usage. Thus, succinct phrases or paragraphs are used to give information on composition or formula, physical constants, "toxicity hazard" ratings or toxicity, fire hazards, disaster control measures, personal hygiene measures, storage and handling, ventilation control, "shipping" regulations, etc. To try to give this amount of information at the rate of nine compounds per page obviously necessitated the extensive use of cross-references, back-references and classification codes. For example, ratings of acute, chronic, local and systemic toxicity are expressed by single figures or letters, meaning "none", "slight", "moderate", "high", or "unknown". For some particularly hazardous or well-documented chemicals, toxicity data are expanded. Less important or less well-known chemicals are very often referred back to related compounds, e.g., "see arsenical compounds", or solvents or ethers, etc. This laudable attempt to be systematic and helpful sometimes goes awry, and, surprisingly, detailed information is sometimes given in surprising places, e.g., on "malt fever", colchicine, n-propyl acetate; or on detailed symptoms produced by some poisons, or on medical treatment in certain cases of poisoning.

There seems rather little rhyme or reason in many of these selections, and one cannot help feeling that editorial fatigue naturally crept in occasionally. However, the book stood up very well to a critical scrutiny of the information given or implied on a large number of representative industrial chemicals.

There was a tendency to find the statement of "details of toxicity unknown" where, in fact, there is published work on the material. But this was admittedly most noticeable with the more recent industrial solvents and agricultural chemicals. No important examples were found of understatement of risks, and the authors seem to have adopted a logically cautious view whenever in doubt.

Preceding this 1000-page compendium are nine chapters, totalling 200 pages by six authors, on toxicology, ventilation control, personal protection and hygiene, atmospheric pollution, fire protection, storage of hazardous materials, allergic diseases in industry, radiation hazards and nuclear reactor safeguards. These nine chapters are of variable value and standards of helpfulness. Those on radiation hazards and reactors are, inevitably, rather complex, and the "non-technical personnel" thought of as readers would find them heavy going. All nine chapters are on subjects difficult to deal with in small compass; most of the information needed to guide a safety effort is in them, however, and several of them should really be read thoroughly before using the book as a reference manual.

The final 150 pages, in small print, deal with the "Shipping Regulations" in force in the United States. Their value to British readers is very limited, therefore, except as a general indication of what needs to be thought of in transporting or dispatching hazardous materials, or as a help to firms indulging in inter-state commerce in America.

This book, although costly, is certain to be useful to those chemists, engineers, safety officers, production supervisors and industrial hygienists or medical men who bear responsibiliity for safety in chemical works, especially to those who are apt to have a lot of new or unfamiliar materials to deal with or advise upon. It fills a big gap for such people, and no other book of its scope is known to this reviewer. The first edition dealt with 5000 materials, this editions deals with 8500. Although the expansion of the second edition has led to some occasionally trying reference systems, those who put their first editions to frequent use will find the extra entries in this second edition of equal value.

However, specialists looking for very detailed information on a chemical will not find it in this book. The data presented are synoptic and brief; they will still leave the specialist to tackle the journals, libraries and less panoramic books when he wants large amounts of information on single subjects.

E. F. EDSON

Air Pollution
Ed. M. W. Thring
Butterworths Scientific Publications, London, 1957, 248 pp., 42s.

THIS book is a welcome addition to the rather meagre literature on clean air. It should be of particular interest to chemical engineers working on atmospheric pollution, since it gives clear practical guidance on many aspects of the subject. In the foreword SIR HUGH BEAVER points out that the solution of our atmospheric-pollution problems must come through the application of science and technology rather than through emotion. Decisions taken without adequate information are almost certain to be wrong. The chemical engineer can play an important part in making the necessary measurements, and it is a pity that the book devotes so little space to this very important aspect of the work.

Many of the authors are experts in their particular subjects, and the book, together with its references, may be said to represent the "best practical advice". No attempt is made to deal with particular solutions to particular effluent problems, and the volume will serve to stimulate interest in the subject rather than a design handbook. All who are concerned with abating atmospheric pollution should have a copy for reference.

One of the section headings refers to the *elimination* of pollution, but a study of the later chapters will confirm the difficulty of doing more than alleviating the worst nuisances. A table shows that 200,000,000 tons of coal with, say, 10% ash are burnt annually in the United Kingdom, and this will lead to an emission of nearly 100,000 tons of grit and dust even if 99.5% of the ash is arrested. Since much of the industrial fuel-burning plant is concentrated in particular areas, it is clear that very high standards of dust arrestment will be required if elimination of pollution is indeed the goal.

All will agree with the editor's view that cheaper means of dust arrestment are desirable. It is difficult to see, however, how this is to be achieved, particularly since the tendency is to require even higher efficiencies than are at present attained. In certain cases solution of the problem might be made easier by avoiding the production of effluents which are difficult to treat, e.g., by modifications to the process, and it is disappointing to find that the book devotes little space to this aspect.

The book is obviously intended for general reading and an opportunity has been missed in the chapter dealing with the spread of gases from chimneys, where a simplification of the presentation of this involved subject might have been hoped for. The mathematical treatment would be a little more palatable if the units used were practical rather than absolute, e.g., contaminant concentrations in parts per million and gas rates in cubic feet per minute.

Nevertheless, the balance between the technical aspects of atmospheric pollution and its effects on amenities has been nicely drawn and the manner of presentation has resulted in a stimulating and readable volume.

C. J. STAIRMAND

Source Book of Industrial Solvents—Vol. 2: Halogenated Hydrocarbons
by I. Mellan
Chapman & Hall, London, 1957, 267 pp., 56s.

THE OPENING section of this book is a short review of the halogens. The four succeeding sections deal with the separate families of halogenated hydrocarbons of the four well-known halogens, that is, excluding astatine. Each section is then introduced with a further more detailed review of the respective halogens before going on to tables of properties of the derivatives including complex derivatives.

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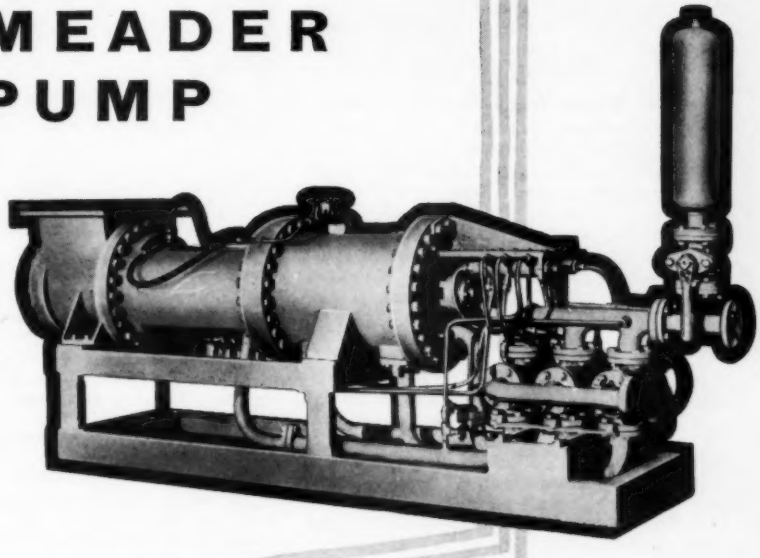

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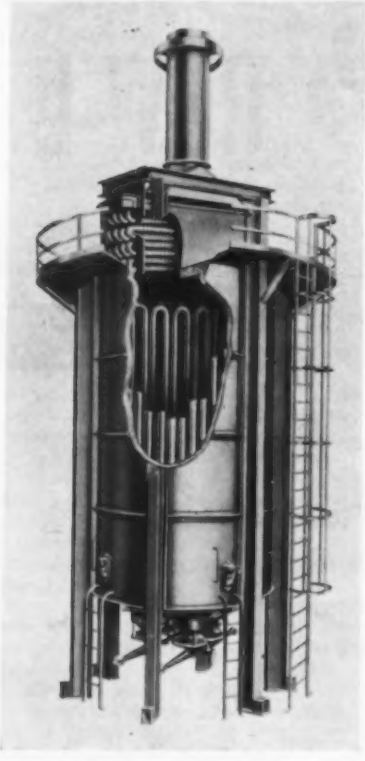
MP 2

PLANT EQUIPMENT NEWS

Heating Equipment

A wide range of industrial heating equipment for operation at high temperatures which has been developed by Struthers Wells, Pennsylvania, U.S.A., over a number of years, is now to be available in Great Britain through a licence agreement between that company and Newton, Chambers. The equipment is supplied in sizes from pilot plant to large commercial units—the capacity of some of the systems already installed overseas is 60 million Btu an hour. Where possible, the equipment is completely assembled in the shop and transported ready for installation in the plant. Larger units are assembled on the spot from simple sections. Complete heating systems containing safety devices, piping and other accessories will be available. The type of heater used on most of Struther Wells' heat-circulating systems is the type C or CV, a vertical heater. The tubular



heaters, the company state, have operated with Dowtherm at temperatures well above those recommended with low thermal breakdown. With hydrocarbon oil, the heaters have been in continuous service for over 20 years without coking or other difficulties. Dowtherm vapour heating systems are among the many systems for which the company designs plant. **Newton, Chambers & Co. Ltd., Thorncliffe., nr Sheffield.**

BCE 3278 for further information

Bus-bar Shield

A new type of insulated conductor, designed to prevent the possibility of shocks through accidental contact, has been introduced by British MonoRail for use on overhead handling systems using conductor bar electrification. The conductor is a straight or curved length of channel section—¾ in. wide, ½ in. deep and ¼ in. thick—made of corrosion - resistant electro-galvanised steel enclosed in an extruded red P.V.C. of a high dielectric strength. The protection, it is pointed out, does not impair the efficiency of the sliding shoe connector. **British MonoRail Ltd., Wren Works, Chadderton, Lancs.**

BCE 3279 for further information

Electronic Temperature Controller

Sifam have just made generally available their Pyromaxim electronic temperature controller. Robustness and dependability have been given special attention in its design and the instrument is available in ranges 0-200°C to 0-1600°C or Fahrenheit equivalents. **Sifam Electrical Instrument Co. Ltd., Leigh Court, Hr. Lincombe Road, Torquay.**

BCE 3280 for further information

New Welding Equipment

Quasi-Arc's new high-lift internal welder can weld internal longitudinal seams in vessels of from 30 in. to 10 ft in diameter and up to 10 ft in length, internal circumferential seams of diameters of 2 ft 6 in. and over, and external longitudinal and circumferential seam welding of vessels up to 10 ft in diameter. **Quasi-Arc Ltd., Bilston, Staffs.**

BCE 3281 for further information

Butterfly and Tandem Valves

ICV hand butterfly valves have been produced specifically for use with combustion equipment on furnaces and similar plant. They are not intended as shut-off valves, but have a wide application for the precise regulation of gas and air supplies. The valve body is an aluminium casting having screwed ends, and finished in grey hammer enamel. The butterfly disc is machined from brass and the shaft and friction discs are of cadmium-plated steel. For those furnace installations where gas and air supplies should be regulated simultaneously, the ICV range of tandem valves has been specially designed to satisfy the need. Gas and air valve bodies are mounted together, each with its own separate linkage. The RQU pulling motor can operate both valves in unison, and it is fitted with two driving discs, one on each side. **The Industrial Pyrometer Co. Ltd., 66-76 Gooch Street, Birmingham, 5.**

BCE 3282 for further information

Air-operated Stirrer

An air-operated stirrer has been added to the range of portable equipment made by Kestners. The prime mover is a

rotary-vane air motor suitable for working pressures of up to 90 psi with integral sun and planet reduction gear driving a stainless-steel or plastic-coated shaft, which is fitted with two opposed propellers. **Kestner Evaporator & Engineering Co. Ltd., 5 Grosvenor Gardens, London, S.W.1.**

BCE 3283 for further information

Slow-close Valves

The Avery-Hardoll slow-close valves have been developed to limit the shock pressures which might otherwise occur if a direct open-close gate-valve type were used. A delay action is caused between full open and shut, and the valve will remain in any position between full open and shut to control speed of flow. The valves are very similar to the pre-set valve on bulkmeters, and are interchangeable, dependent on the purpose for which the vehicle has been designed. The action of the slow-close valve depends on the differential pressure obtaining on either side of the main valve. This pressure is controlled by a pilot valve which opens or closes, thus allowing flow through the pilot valve hole in relation to the flow through the orifice in the main valve. The valves are available in the sizes 2½ in. and 3 in. **Avery-Hardoll Ltd., Oakcroft Road, Tolworth, Surrey.**

BCE 3284 for further information

Rubber Control Valve

The Sala rubber control valve is designed to provide a round hole down to a very small part of the full area of the valve and to cause a Venturi flow pattern. The makers suggest its use particularly for pulps and slurries. The low friction of a streamlined flow through a round hole and the cushioned action of a very thick rubber wall aid the abrasion resistance of the equipment, it is pointed

New Sharples Super-D-Hydrators

in the world's most complete range of centrifuges

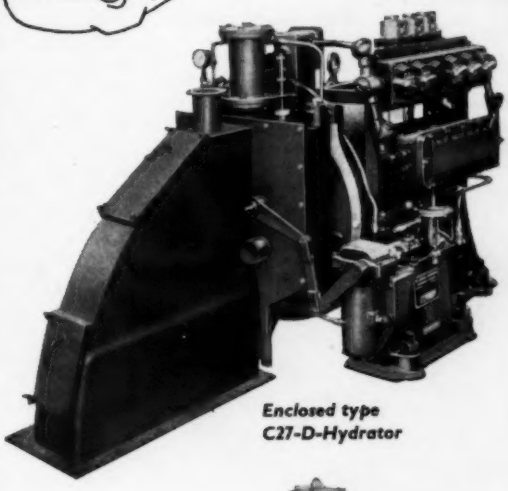
The Sharples range of centrifuges—the most complete in the world—now includes new models of Super-D-Hydrator. This now means that there is a Sharples answer for every problem of crystal filtration and drying.

The new C41 Super-D-Hydrator extends the capacity range upwards whilst maintaining the high centrifugal force characteristic. Models are available for open or for enclosed operation with toxic or hazardous materials for washing at elevated temperatures and under refrigerated conditions. Special units are built for handling sterile materials such as for antibiotic separation.

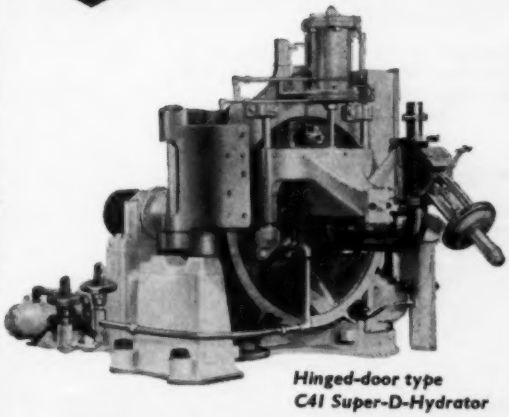
The basic design of the Super-D-Hydrator is a completely automatic continuous centrifuge of the perforated basket type. It is suited to separating, washing and dehydrating slurries of all forms of crystals, from the coarsest to the finest.

The big advantages of the Sharples Super-D-Hydrator are the big economic advantages in labour due to completely automatic operation and the consistent quality of the product.

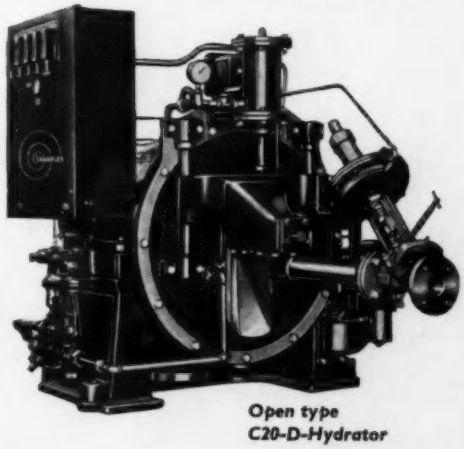
If you have a separation problem you are invited to write to the address below or 'phone Camberley 2601 and talk it over with Martin Trowbridge.



Enclosed type C27-D-Hydrator



Hinged-door type C41 Super-D-Hydrator



Open type C20-D-Hydrator

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SHARPLES CENTRIFUGES LTD., TOWER WORKS, DOMAN ROAD, CAMBERLEY, SURREY. *Telephone: Camberley 2601*

PLANT EQUIPMENT NEWS

out. Adjustment of the diameter of the valve is controlled through a hydraulic pressure-operator and the diameter of the valve is proportional to the hydraulic pressure on the outside of the rubber bushing. The valve is not recommended for use as a shut-off valve except for short periods. **Neldco Processes Ltd., Ashford, Middx.**

BCE 3285 for further information

Extension to Blower Range

A 12-in. machine has been added to Holmes-Connersville range of roller bearing blowers, and both this and the 10-in. model are now equipped with the

redesigned H-type casing shown in the illustration. **W. C. Holmes & Co. Ltd., Turnbridge, Huddersfield.**

BCE 3286 for further information

Drip Regulator

R. O. Harris have produced a new automatic drip regulator for Condesco Products Ltd. The various parts are machined from solid block and rod perspex to engineering precision standards, and the units are intended to dispense all types of liquids, acid or alkali, in droplet form. Specially suitable for use on bottle and churn plant in dairies and breweries, they also find applications in other industries where small, accurate and continuous quantities of corrosive or non-corrosive liquids are required. The regulators are supplied in sizes of 1 and 5 gallons. **R. O. Harris & Co. Ltd., Cambridge Works, Bedford Road, London, N.2.** **BCE 3287** for further information

Pharmaceutical Valve

Alexander Controls have developed a solenoid-opened valve especially for use with pharmaceutical preparations including vaccines. It is easily taken apart for sterilising and contains no solder work. All the metal parts in contact with the liquid are of corrosion-resisting material. It is being made in sizes of up to 1 in. in diameter. **Alexander Controls Ltd., Reddicap Hill, Sutton Coldfield.**

BCE 3288 for further information

Viscous-fluid Mixer

The Moritz Turbo-Cleaver has been designed for mixing—homogenising—and dissolving processes with viscous products. It makes use of an impeller which

has cutting vanes and an outer stationary crown which acts as a baffle and increases the cutting action of the blades. The impeller is large to avoid cavitation in very viscous mediums, and the vessel is provided with bottom-entry drive. Among the applications for which it is being used are the preparation of ceramic slip and Neoprene- or rubber-based glues and adhesives. It may be jacketed for heating and cooling. The equipment is made in the sizes 44-660 gallons capacity. **Moritz Chemical Engineering Co. Ltd., 204 Earls Court Road, London, S.W.5.**

BCE 3289 for further information

Protected Fans

In conjunction with M.M. Plastics Ltd., Fan Equipment Corp. have now produced a range of S.C.B. fans coated with Neoprene for use with corrosive and abrasive gases and dust, suspensions, etc. The coating is at least 0.012 in. thick and is said not to embrittle with age or exposure. The process has been in use on high-duty fans on the Continent. **Fan Equipment Corporation Ltd., 26 Great James Street, London, W.C.1.**

BCE 3290 for further information

Geared Motors

Electropower Gears are now marketing variable-speed geared motors in Great Britain under the Brottby patent within the range ¼-25 hp. They are also supplying an infinitely variable speed electronic control unit for their geared motors and speed reducers within their standard range of 1-3 hp. **Electropower Gears Ltd., Kingsbury Works, Kingsbury Road, London, N.W.9.**

BCE 3291 for further information

Other Items of interest

Hallam, Sleigh & Cheston announce that their Widney Dorlec Quick-Fit system of cabinet framework is being used for the construction of scaffolding for the support of large-scale glass chemical plant. **Hallam, Sleigh & Cheston Ltd., Bagot Street, Birmingham, 4.**

BCE 3292 for further information

H.F. Industrial Services have produced a high-frequency P.V.C. welding machine which is capable, with the use of interchangeable platens and tools, of meeting a wide variety of the needs arising in the use of P.V.C.—including bag-sealing. **H.F. Industrial Services Ltd., 317 High Road, Wood Green, London, N.22.**

BCE 3293 for further information

A new metal spraying gun, Metco, type K metallising machine, has been introduced by **Metallizing Equipment Co. Ltd., Chobham, Woking, Surrey.**

BCE 3294 for further information

The latest addition to the Black Knight range of plastic products is a 13-gallon (60,000 cc) polythene container with fitted plastic tap. The container is specially reinforced and threaded so that the tap can be screwed in to give a perfect, liquid-tight fitting. **Tool Treatments (Chemicals) Ltd., Colliery Road, Birmingham Road, West Bromwich.**

BCE 3295 for further information

The Schlegel system of reconditioning used oil, elaborated by Schlegel Bros., Stuttgart, is now being handled in the United Kingdom and Eire by Liquid Systems. The regenerators use distillation, adsorption and filtration, and can also be used for petrol, turpentine, kerosene, trichlorethylene and other liquids. **Liquid Systems Ltd., Norwich Union House, Wellesley Road, Croydon.**

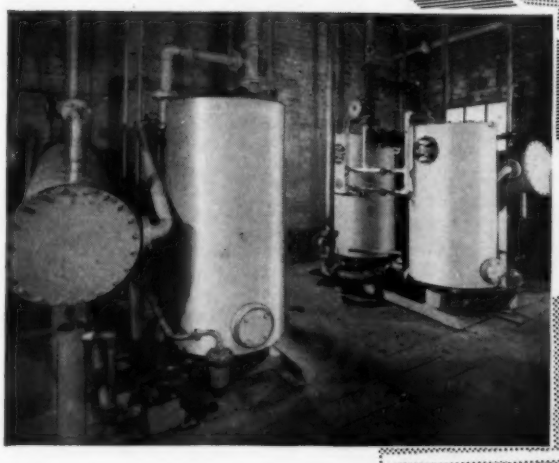
BCE 3296 for further information

New Foreign Equipment

Continuous Mixer

Rheinhutter have developed a continuous centrifugal mixer, type R.D.M., which can be inserted into a pipe system, uses no mixing vessel, is self-priming, and is energised by direct drive without gear. It may be equipped with an accelerator on the mixing impeller shaft. The

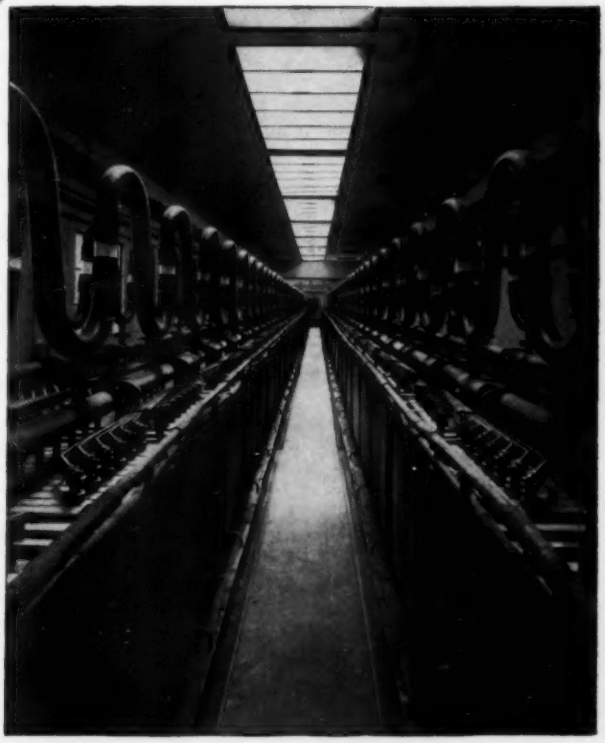
Drying Hydrogen for Carbide Tools



In the manufacture of Prolite tungsten-carbide tools, Murex Limited use Birlec adsorption dryers to remove water vapour from their electrolytic hydrogen supply. The hydrogen is dried to a dew-point of minus 70°C for use in the reduction and sintering furnaces and the high quality of the product depends on the stringent moisture control. Birlec moisture adsorbers are available in a range of standard sizes for varied industrial applications including the drying of compressed air and the dehumidification of factories and stores.

Illustration above:—
Birlec adsorbers for hydrogen drying.

Illustration right:—
Electrolytic hydrogen plant at Murex Limited.



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DRY AIR & GASES

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SM/B 3060D/PG

PLANT EQUIPMENT NEWS

mixing bowl and the impeller, the makers point out, are designed so that the shear forces and eddies generated by the impeller are intensified by the bowl. The dimensions, number of mixing stages, speed, power consumption and materials of construction of the mixer may be varied widely to suit particular problems. The equipment is intended for the continuous mixing of a liquid with a solid, gas, or other liquid. If suspensions of solids are to be prepared, the inlet pipe is normally inclined downwards and it may be fitted with a screw conveyor, whereas if the disperse phase is a gas the inlet should be inclined upwards. The mixing bowls are built as double cones. A centrifugal impeller is usually used, but other types of rotor may be fitted for special purposes, the size of the impeller and bowl being determined by the throughput and the mixing period required. Mixing can be carried out in a number of stages—for low mixing speeds large bowls or several bowls in series are arranged, but at high mixing speeds small bowls are usually sufficient. A series may be specially suitable where a number of components has to be added. By varying of the impeller speed and by inserting flow disturbing elements into the equipment, the intensity of mixing may be adjusted. For large outputs a parallel arrangement of mixers can be set up.

The accelerator serves to counteract friction through the apparatus or to overcome back pressure at the exit tube. It is of particular importance in self-priming mixers as self-priming is possible only if the pressure at the impeller inlet is below atmospheric. The accelerator is usually in the form of a propeller with guide vanes, but for viscous liquids it may be in the form of a screw. The most favourable position for a continuous impeller is near the end of the pipe system, because there is then only small back pressure at the outlet branch. **Rheinhütte, Wiesbaden-Biebrich.** *Representative:* **Dr. Ing. W. F. Reister, 9 Great Putteney Street, London, W.1.**

BCE 3297 for further information

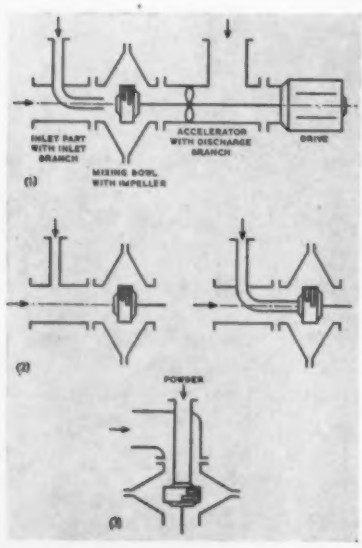


Diagram of the mixer, showing (1) *general design, and,* (2) *and* (3), *some arrangements of the components.*

Scratch and Pit Measurer

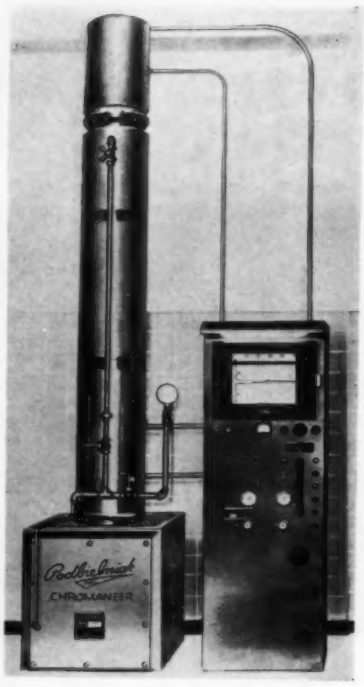
Boeing Airplane Co., Seattle, Washington, have developed a new optical instrument for measuring the depth of scratches and pitted areas on the outside surfaces of metallic sheet and tube. The

new instrument, 7 in. high, has a set of lenses with 36X magnification, and it works on the principle used by astronomers for measuring the depth of moon craters. Light strikes the bottom of the scratch or pit at a known angle and the length of the shadow is measured by the instrument. Calibrations on a simple adjustment knob give depth measurements to 0.0001 in. **Boeing Airplane Co., Seattle, 24, Washington, U.S.A.**

BCE 3298 for further information

Chromatographic Separator

Vapour-phase chromatography has been extended to the industrial purification of liquid or gaseous materials by Podbielniak in their vapour-phase Chromaneer plant. The method yields, it is claimed, a product of extreme purity, regardless of the boiling point of contaminating materials. The separations are based on vapour-phase chromatography, with partition or adsorption columns, eluted with air or nitrogen. The process, which is continuous and automatic, is suitable for purifying products that are made in small quantities; for example, silicon tetrachloride for the production of silicon transistors; flavouring oils and extracts; perfumes; certain "fine" chemicals; and highly pure materials used as standards. The plants are available in columns of 2-4 in. in diameter, and of 20 ft and more in length. Their capacity is 10 to 25 cu. ft of gaseous product, or 1 to 2 quarts of a liquid product per day, the capacity varying with purity of charge and length of time cycle. The columns are thermostatted for operation at any temperature from 25°C to 200°C, and



the composition of the exit gas is monitored and recorded continuously. **Podbielniak Inc., 341 East Ohio Street, Chicago, 11, Illinois.**

BCE 3299 for further information

New Instruments

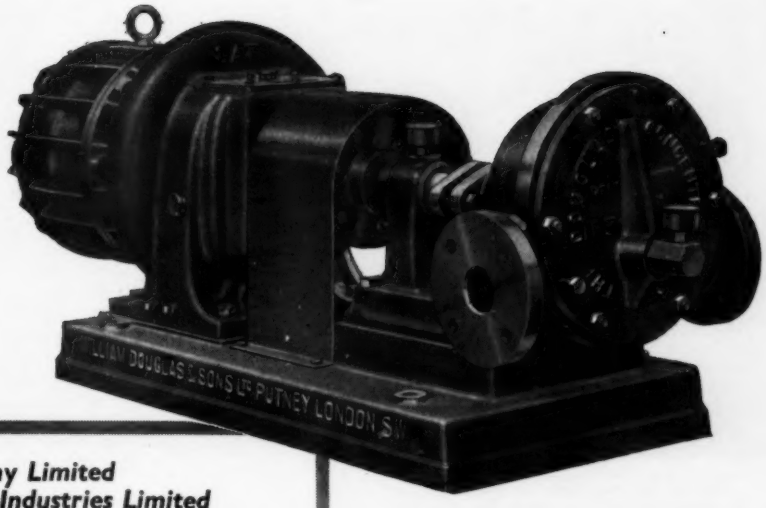
Newly-patented non-glass electrolytic conductivity-measuring cells are being manufactured by Electronic Switchgear. The cells, for direct installation in the electrolyte flow line, have annular, impervious carbon electrodes which are flush with the bore of the cell. The cells are simple to clean, and they do not restrict the through flow of liquid. The cell bodies, into which the electrodes are moulded, are of an inert plastic material that is resistant to attack by 10% solutions of sulphuric acid, hydrochloric acid and caustic soda. The cells are suitable for pressures and temperatures up to 150 psi and 80°C. This CCA series of cells is suggested for application on base exchange water softening plant, demineralised water plant and for appraisal of soda ash content in sugar syrup, etc. The CCB series is of a particularly heavy-duty pattern, and is designed for use in conditions of extreme pressure and temperature. The RC4 conductivity controller is intended primarily for permanent installation on processing plant in which it is required to signal when the monitored conductivity of an electrolyte reaches a predetermined value. **Electronic Switchgear (London) Ltd., 47 Victoria Street, London, S.W.1.**

BCE 3300 for further information

An electrically-operated integrator is now available as a standard fitment to the Arkon V-notch liquid flow-recorder when the equipment is required to show

BCE 3218 for further information

Britain's Busiest Pump



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You will find Douglas Pumps at work in most of Britain's largest concerns. Many of these pumps have been in *continuous* operation for a very long time, in some instances since the 1930's, requiring only routine maintenance. The liquors and semi solids they handle vary from acids and solvents to tallow and tar. A complete range of models is available and service and advice freely given. Please write for details.

The Douglas Pump has given excellent service on many different duties in the Chemical Industries. May we have the opportunity of placing this service at your disposal too?

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PLANT EQUIPMENT NEWS

the total quantity of flow over a period. The index is visible through the recorder window above the chart mechanism. Operating on a 30-sec. cycle, the integrator adds up a series of spot readings and

is stated to be accurate, therefore, despite fluctuations in rate of flow. **Walker, Crosweller & Co. Ltd., Cheltenham.**

BCE 3301 for further information

The S7 X easy-clean meter has been developed by Measurement for metering potable liquids. It may be dismantled by undoing four knurled clamping screws. All the metal components in contact with the liquid are made from stainless steel. Measurement have also developed to prototype stage a rate of flow meter which uses no external power supplies. **Measurement Ltd., Dobcross, Oldham, Lancs.**

BCE 3302 for further information

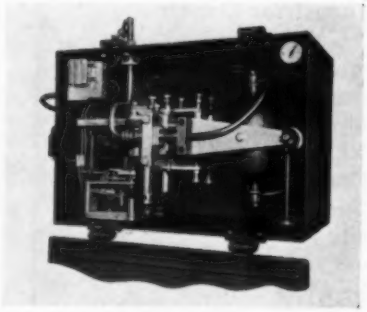
Non-mercurial instruments for flow, level, specific gravity, etc., are the latest additions to the Kent Commander class of industrial instruments. They incorporate the Barton patented differential-pressure unit, which—although employing sensitive bellows for its actuating element—is designed to be subjected to pressure differences equal to the pressure rating of the instrument without damage. The company has also introduced an electronic instrument for oxygen measurement which works in association with the Kent paramagnetic oxygen analyser. **George Kent Ltd., Luton, Bedfordshire.**

BCE 3303 for further information

New instruments from K.D.G. include a pneumatic continuous-reading tank-contents gauge. The stand pipe is positioned vertically in the tank or vessel with the open end just above any expected sludge level. The indicating unit is then positioned suitably. Air is then introduced into the system and this causes all liquid to be expelled from the stand pipe. Balancing the static head of the liquid in the tank enables a reading to be shown on the calibrated tank contents indicator. The company is also offering a range of precision-made Bourdon tube pressure resistance transducers. Their accuracy is stated to be ±1% for all ranges except 0-2000 psi and 0-4000 psi, for which it is ±1½%. Flameproof pressure switches, types SP-1026 and SP-1027, are designed to meet the requirements of BSS.229. They are fully approved by the Ministry of Fuel and Power for Groups 2 and 3. Buxton certificate No. FLP. 3369 are also being supplied. **K.D.G. Instruments Ltd., Manor Royal, Crawley, Sussex.**

BCE 3304 for further information

A density meter for "clean" liquids has been developed by Rotameter on the continuous principle of their established slurry-density equipment. The clean liquid is fed through a spherical vessel and changes of density are detected by the pneumatic force-balance which transmits a 3-15 psi air output signal linearly related to density change. A maximum sensitivity of 0.03 g./ml. for full-scale deflection is obtainable and working pressures up to 75 psig can be accommodated. It was designed for accurate fuel-density measurement in connection with aircraft engine pilot test plant, but is being supplied for wider applications.



The company's metric Rotameters, types 907 and 914, are fitted with improved metering tubes and glands which reduce the danger of glass breakage during overhaul. Interchangeable components have been used so far as possible in their design. **Rotameter Manufacturing Co. Ltd., Purley Way, Croydon, Surrey.**

BCE 3305 for further information

Heat Exchangers have developed recently a range of packaged temperature-control units for use with process fluids, steam-heated rolls, etc. They are designed to maintain fluid temperatures to within ±1°F of a pre-set level, and will provide a controlled rate of rise or fall of temperature of as little as 1°F per minute. **Heat Exchangers Ltd., 1 Wardour Street, London, W.1.**

BCE 3306 for further information

The Uvispek spectrophotometer is now fitted with a prism of synthetic fused silica, which is much more transparent than quartz at wavelengths below about 2500 Ångströms. **Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.**

BCE 3307 for further information

New Publications

Two pocket-sized booklets describing the opportunities for graduate scientists in research and development with United Steel have recently been published. A further one on "Training" for student apprentices is also available from **The United Steel Companies Ltd., 17 Westbourne Road, Sheffield, 10.**

BCE 3308 for further information

"Sight Flow Indicators" is the title of a recent informative folder by B. Rhodes & Son Ltd. on their range of S.F.I.s. The company say that their products are manufactured for any fluid and in any metal and can be modified or designed for all requirements. Copies from **B. Rhodes & Son Ltd., Queen Street, Romford, Essex.**

BCE 3309 for further information

"Hydraulic Clamping" is the title of a new brochure by Power Jacks. It describes the principle of operation, method of assembly and applications for the company's Newton hydraulic clamping system. Copies from **Power Jacks Ltd., Maylands Avenue, Hemel Hempstead, Herts.**

BCE 3310 for further information

A new Monsanto publication details the applications for the Anoclors and Pyroclor dielectric fluids produced by **Monsanto Chemicals Ltd., Victoria Street, London, S.W.1.**

BCE 3311 for further information

The latest brochure by Hygrotherm deals with heat-transfer systems. It covers indirect heat transfer, heat generators, distillation plant, jacketed vessels, Hygrotherm systems and specifications for fine organo-silicate heat-transfer systems. Copies from **Hygrotherm Engineering Ltd., 5 Fitzharding Street, London, W.1.**

BCE 3312 for further information

Ferranti have recently revised two booklets on their Pegasus computer. The first (List DC10A—second edition) gives a general picture of the computer and its principal features as they concern the user. The other, List DC26A, is a more "popular" brochure, but one which provides sufficient detail to enable those interested in this type of equipment to grasp the computer's essential features. Both booklets deal with the computer and its magnetic tape auxiliary equipment. Copies from **Ferranti Ltd., 21 Portland Place, London, W.1.**

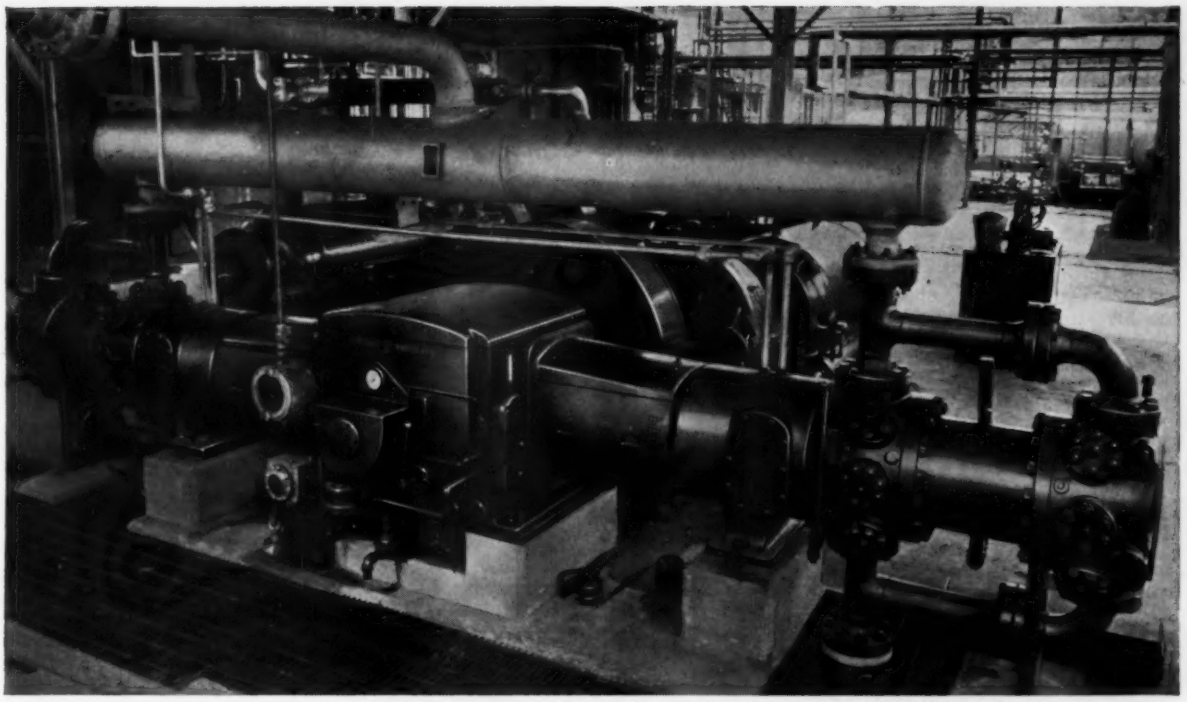
BCE 3313 for further information

A new pamphlet by Walker, Crossweller & Co. Ltd. explains the working principle, sizes available, construction, rates of flow and working pressure, and a number of suggested applications for this company's Arkon flow indicators. Copies from **Walker, Crosweller & Co. Ltd., Cheltenham.**

BCE 3314 for further information

A neat, hand, easy-to-file folder containing a selection of their pamphlets describing their electrical control instruments has been received from **Sorvomex Controls Ltd., Crowborough Hill, Jarvis Brook, Sussex.**

BCE 3315 for further information



Class FE single-stage non-lubricated hydrogen recycle compressor boosting to 660 p.s.i. at work on refinery service.

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5000 c.f.m. or 3000 lb p.s.i.

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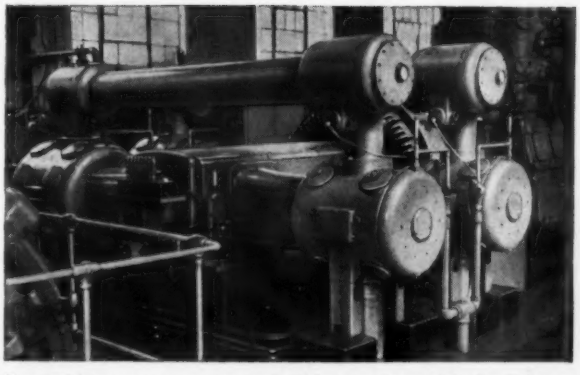

Class FE 42 two-stage compressor designed for operation at 3600 c.f.m. F.A.D. at 100 lb. pressure.

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- **Vibration free — require minimum foundation work.**
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Month's News in Brief

Fewer Works Registered Under 1957 Alkali Act

Reduction in the number of works registered under the Alkali Act at the end of 1957 was due to concentration of manufacturing operations and not to any lessening in activity or lower production in the processes involved, states the Chief Alkali Inspector for England and Wales in his annual report ("94 Annual Report on Alkali, etc., Works by Chief Inspectors, 1957." H.M. Stationery Office, price 3s.). The number of works registered under the Alkali Act at the end of the year was 872, involving the operation of 1733 separate processes—a decrease of 17 works and 14 processes compared with 1956.

During 1957, 4023 visits and inspections were made. Complaints were most numerous against cement works (11) and fertiliser granulation plants (9). Among non-registered works, complaints against carbonising plants (gas works and coke ovens (7)) headed the list. In seven cases the total acidity of gas emissions exceeded statutory limits, and 10 infractions related to failure to use "best practicable means" to prevent escape of noxious and offensive gases. The reduction in the number of infractions (23 in 1956 and 48 in 1955) indicates continuing improvement in supervision and maintenance.

At 2,137,000 tons, sulphuric acid production again showed a rise (2,056,000 tons in 1956 and 821,000 tons in 1938) although the number of works registered is less than before the war. The report further states that there has been continuing installation of means to prevent emission of acid droplets, but warns that "any future trouble due to emissions at a chamber or tower plant which can be traced to droplet emission will rightly be regarded most seriously".

The Chief Inspector for Scotland in his report says that work outside the Clean Air and Alkali Acts, including work on the safe disposal of radioactive wastes, has encroached on the time usually devoted to them. At the end of the year there were 71 works registered in Scotland involving 101 processes requiring inspection—a decrease of 9 and 13 respectively compared with 1956. During the year 148 inspection visits were made. Three infringements—all at sulphuric acid works—were found, but none appeared to be deliberate evasions. Five complaints were made about fumes from registered works—three of them about granulated fertiliser plants and two about paraffin oil works.

Chemical Engineering at Edinburgh

The third extension of the Heriot-Watt College, including the new chemical engineering laboratories, are to be opened by the Duke of Edinburgh on July 3. When it was decided to establish chemical engineering at Edinburgh it was agreed between the University and the Heriot-Watt College to set up a joint department in order to avoid duplication of staff and facilities. Since the College at that time was building its Third Extension, accommodation for the department, amounting to about 10,000 sq. ft, was conveniently provided in the new premises. The facilities for chemical engineering include two unit operations laboratories, two large research laboratories, library, workshop, tutorial rooms, staff rooms and stores. The department provides for students taking the degree of Bachelor of Technological Science of the University or for the Associateship in chemical engineering of the College. Within the University the department is in the Faculty of Science and is known as Chemical Technology, a chair in this subject having been first established in 1855.

Shell's £50 million Orders

Business to a total value of £50 million was placed with British industry, and spread over some 3500 firms, by the Royal Dutch/Shell Group of Companies in 1957. Additionally, many millions were spent on the construction, repair and victualling of the Shell tanker fleet and on the petro-chemical side of the business. Of the 3500 British suppliers affected, one received orders of over £5 million, five others of over £1 million and 67 of over £100,000.

Proposed Courses

A refresher course organised by the North Wales Fuel Efficiency Panel of the Welsh Joint Education Committee in co-operation with the National Industrial Fuel Efficiency Service will be held at the Prestatyn Holiday Camp, North Wales, from June 9 to 14. The title of the course will be "The Clean Air Act and Atmospheric Pollution arising from Combustion Processes". Further details may be obtained from the secretary to the Course, Mr. C. K. R. Davies, N.I.F.E.S., Baltic House, Mountstuart Square, Cardiff.

The next standard Harwell Reactor School course on which places are available will commence on September 1, 1958, and finish on December 23, 1958. Application forms for the course, which is open to British and overseas students, and further details may be obtained from: The Principal, Harwell Reactor School, Atomic Energy Research Establishment, Harwell, Berkshire, England.

Management Training (P.E.) Ltd., 12 Grosvenor Place, London, S.W.1, have issued booklets on their current courses for management training. Copies of these booklets will be sent, on request, to interested parties.

News Briefs

Northern Aluminium Co. Ltd. announces that a central buying department, located at the company's head office in London, has been established. Mr. D. A. Corbett-Thompson, formerly export sales manager, has been appointed chief purchasing officer. The buying departments of the company's three works at Banbury, Birmingham and Rogerstone, Mon., will continue to function.

Chemical Construction (Great Britain) Ltd. have received a further contract from British Titan Products Co. Ltd. for a 250 tons per day contact sulphuric acid plant to be erected at Billingham. This will be the fifth sulphuric acid plant which the company have supplied to British Titan Products Co. Ltd.

I.C.I.'s Heavy Organic Chemicals Division at Billingham, Co. Durham, is to build a new plant for the extended production of octylphenol and other alkylated phenols. Only recently I.C.I. announced a substantial reduction in its home trade price for octylphenol to a level which is closely comparable with the American domestic price.

Elliott Bros. (London) Ltd.'s power plant division, has moved to larger office premises at Dalston Gardens, Stanmore, Middlesex (Tel.: WORdsworth 0269). Their associates, James Gordon & Co. Ltd., have themselves only recently taken over greatly enlarged premises at this address.

Henry Hawkins Ltd. have been granted by the B.A.S.F. of Ludwigshafen, West Germany, the sole licence for the manufacture and sale of Pall tower packing rings in the British Isles.

Barlow-Whitney Ltd.'s Midlands office has been removed to 44 Queen's College Chambers, Paradise Street, Birmingham, 1. Tel.: Midland 6897.

Warren, Morrison Ltd. have moved to 41 St. James's Place, London, S.W.1. Tel.: MAYfair 9895.

The British Sulphur Corporation Ltd. has moved to Fison House, 95 Wigmore Street, London, W.1. Tel.: WELbeck 5500.

George Cohen Sons & Co. Ltd., Raw Materials Division, has moved to Trinity Road, Kingsbury, Tamworth, Staffs. Tel.: Hurley 281/2 or Ashfield 1191/3.

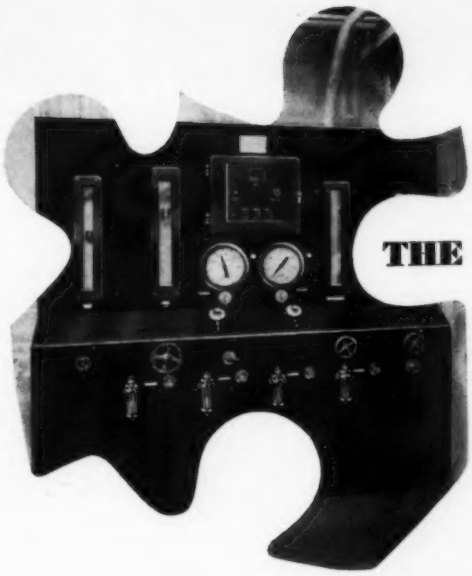
The trading name of the Horace Priest Chemical Engineering Co. Ltd., has been changed to The Beverley Chemical Engineering Co. Ltd., and their address to Beverley House, London Road, Horsham. Tel.: Horsham 3211 and 3212.

Premier Colloid Mills Ltd., in association with their Northern agents, O. O. Robinson (Leeds) Ltd., have recently opened a modern laboratory at Glebe House, Hollin Lane, Leeds, 16. Tel.: Leeds 54131.

Wayne Tank & Pump Co. Ltd. are now resident in their new premises at Western Road, Bracknell, Berks, to which address all future communications should be sent.

The Glasgow offices of Igranic Electric Co. Ltd., of Bedford, have recently moved into new premises at 242 West George Street, Glasgow, C.2. Tel.: City 4537 and 4538.

The following changes have been made in the sales and service arrangements of Goring Kerr in the North of England. Murray Swanson Ltd., Heriot House, Newcastle upon Tyne, 4, have been



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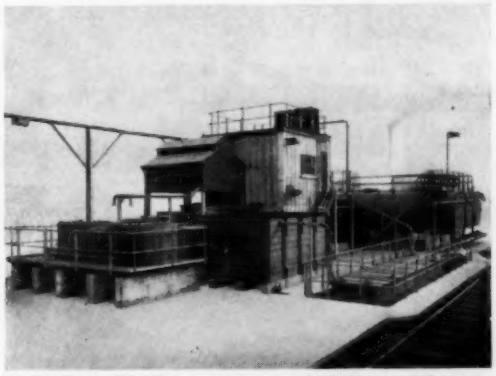
The Mills Packard Organisation is equipped to handle the design, development, extension or rebuilding of chemical plant—a complete chemical engineering service to users in the chemical, gas, fertilizer, oil, metal and allied industries. Keeping up-to-date with the latest developments in the use of specialised equipment, such as the instruments shown on the panel on the left, enables us to provide the best available installation design for any particular plant however big, however small. Call in our technical consultants at an early stage on any projected installation, and you are sure of a well designed plant incorporating first-class materials and workmanship.

AND THE WHOLE

Shown on the right is a Mills Packard Sulphuric Acid Storage and Dilution Plant, of which the instrument panel shown above forms an important part. We will be pleased to provide details of other projects successfully completed for chemical plant users in a variety of industries.



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Wherever pipe-work is subjected to vibration and movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

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BCE 3221 for further information

appointed to handle the company's metal-detection and level-control equipment in Cumberland, Northumberland, Westmorland and Durham. Instruments & Controls (J. L. Record) Ltd., Sandiway Place, Manchester Road, Altrincham, Cheshire, will continue to act as sole sales representatives for the metal detection equipment in the North-west of England. Here, however, a separate level-control division has been formed and it will be handled by Mr. J. D. Withington, 13 Cambridge Avenue, Great Crosby, Liverpool, 23.

People in the News

Mr. L. H. Manderstam, of L. H. Manderstam & Partners Ltd., has been seconded for one year to act as director of operation of the recently-formed Middle East Industrial Development Projects Corporation (MIDEC) S.A. Announced by the Federation of British Industries, the new company's registered office is at Rue Aldringer No. 14, Luxembourg. Present participating countries in (MIDEC) S.A. are America, Belgium, Canada, Denmark, France, Great Britain, Western Germany, Holland, Italy, Norway, Sweden and Switzerland. Total initial share capital of the company is Swiss Francs 1 million.

Mr. H. P. Matthews has been appointed managing director of Zwicky Ltd.

The Council of the Institute of Metals has made the following awards of medals for 1958: *The Institute of Metals Medal in Platinum* to **Professor Emeritus Robert Salmon Hutton,** M.A., D.Sc., in recognition of his outstanding work in connection with the science and practice of non-ferrous metallurgy; and the *Rosenhain Medal* to **Dr. John Herbert Hollomon** in recognition of his outstanding contributions to knowledge in the field of physical metallurgy.

Mr. S. H. Clarke, C.B.E., has been appointed as director of the new research station now being built for the D.S.I.R. at Stevenage for fuel and process research. Mr. Clarke is the present director of the Fire Research Station at Boreham Wood, run jointly by the D.S.I.R. and the Fire Offices' Committee. The programme of the new station will include, as major items, researches on atmospheric pollution, the production of oil from coal and aspects of mineral processing.

James M. Gavin has been elected vice-president and a director of Arthur D. Little Inc. Mr. Gavin will assume his duties as an administrative officer of the company on June 1.

The appointment of **Mr. G. Horsley** to the board of Crofts Engineers (Holdings) Ltd., and also his appointment as joint managing director of the operating company, Crofts (Engineers) Ltd. has been announced.

Mr. L. Pale has been appointed Northern Area technical sales representative for Q.V.F. Ltd. He will be responsible for Q.V.F. technical sales throughout the North of England.

Mr. G. Boex, a former managing director of the British Aluminium and Associated Companies, retired from the board by rotation on May 6, 1958. Owing to advancing years, he does not wish to seek re-election, but will continue in a consultative capacity.

Mr. P. A. Ashby has been appointed engineer in charge of design and sales of chemical plant by Freeman Taylor Machines Ltd., Necton Street Works, Syston, near Leicester, specialists in the manufacture of stainless-steel plant. This appointment coincides with the firm having secured the sole manufacturing licence and agency for the U.K., Eire and the Commonwealth for Olsa of Milan, designers and manufacturers of chemical and pharmaceutical plant, stainless-steel valves and ancillary plant.

P. A. Ashby

C. L. Smith

Mr. C. L. Smith has been appointed project engineer (Northern England) of Sharples Centrifuges Ltd. to assist **Mr. G. H. Duffield**, the senior project engineer of that area.

Dr. E. W. R. Steacie, president, National Research Council of Canada, has been elected an Honorary Fellow of the Chemical Society of London. Dr. Steacie's principal work is in the field of gas reactions and photochemistry, which is important as the basis of petroleum technology.

Huntington, Heberlein & Co. Ltd. (subsidiary of Simon-Carves Ltd.) announce that **Mr. A. T. Rogers**, chief engineer, and **Mr. R. F. Jennings**, in charge of the sinter section, have been appointed technical directors.

Mr. M. Wiseman has been appointed as a contract engineer in The Metal Industries Division of Electroflo Meters Co. Ltd. **Mr. A. G. Perring**, formerly of Fischer & Porter Ltd., has joined Electroflo Meters Co. Ltd. as systems engineering representative covering the process industries for the North of England and Scotland, based upon Stockport. The appointment of **Mr. W. A. Thompson** and **Mr. R. D. Honey** as contracts engineers in the Power Generation Division of Electroflow Meters Co. Ltd. has also been announced.

Mr. B. H. Turpin, managing director of Q.V.F. Ltd., has been appointed managing director of Quickfit & Quartz Ltd. He succeeds **Sir Graham Cunningham**, who continues as chairman. **Mr. J. D. Nuttall**, director and secretary of the parent company, the Triplex Safety Glass Co. Ltd., has resigned from the board of Quickfit & Quartz Ltd.

Mr. G. McOnie has been appointed a director of Pilkington Bros Ltd., glass manufacturers.

Mr. R. H. E. Thomas, marketing member of the National Coal Board, has been appointed chairman of the Solid Smokeless Fuels Federation. He succeeds **Sir Henry Jones**, who, at the special request of the executive, continued in office beyond the normal term.

Coming Events

Home

June 4. Scottish Branch of the Road Research Laboratory of the D.S.I.R. and also the Mechanical Engineering Research Laboratory at Thorntonhall, near Glasgow, will be open to visitors **until April 5.**

June 9. *Symposium on Interferometry:* At the National Physical Laboratory, Teddington, Middlesex, **until April 11.**

June 9. *Conferences of the International Organisation for Standardisation:* At the Royal Hall, Harrogate, **until June 21.**

June 10. *Institution of Civil Engineers Annual General Meeting:* At the Institute, Great George Street, Westminster, London, S.W.1. **5.30 p.m.**

June 10. *Society of Chemical Engineers, Chemical Engineering Group:* At 14 Belgrave Square, London, S.W.1. "Glass as a Material of Construction in the Chemical Industry. **5.30 p.m.**

June 11. *The 12 Building Plant Exhibition*, at Edgbaston, Birmingham, **until June 18.**

June 18. The Chemical and Petroleum Engineering Exhibition at Olympia, London, until June 28.

June 24. Joint Symposium on the Organisation of Chemical Engineering Projects at Olympia, London, until June 26.

Overseas

May 25. *Air Pollution Control Association 51 Annual Meeting:* At Philadelphia, Pa., **until May 29.**

May 26. *The Chemical Institute of Canada, 41 Annual Conference and Exhibition:* At the Royal York Hotel, Toronto, Ontario, **until May 28.**

May 30. *Exposition Suisse de Produits Importes:* At Zürich, **until June 8.**

May 31. *12 Exhibition and Congress of Chemical Plant:* At Frankfurt/Main, **until June 8.**

June 2. *Symposium on the Peaceful Uses of Atomic Energy:* At the University of Sydney, Australia, **until June 6.**

June 9. *International Automation Congress and Fourth International Automation Exposition:* At New York, U.S.A., **until June 13.**

June 9. *Study and Documentation of Water* (Cebedeau) International Meetings at Brussels (June 9), and Liége (June 10-14), **until June 14.**

June 16. *Fifth International Congress and Exhibition of Electronics and Nuclear Energy*, Rome, **until June 30.**

June 17. *Annual Session and Technical Meetings of International Institute of Refrigeration, Commission 1 (Physics of Very Low Temperatures):* At Delft, Netherlands, **until June 21.**

June 17. *International Congress on Metallurgical Research:* At Liége, Belgium, **until June 21.**